E3S Web of Conferences **387**, 02003 (2023) https://doi.org/10.1051/e3sconf/202338702003
ICSERET-2023

Smart Energy Consumption Control in Commercial Buildings Using Machine Learning and IOT

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Abstract. In recent years, the use of artificial intelligence (AI) techniques such as Artificial Neural Networks (ANNs) and Support Vector Machines (SVMs), in combination with the Internet of Things (IoT), has gained significant attention for optimizing energy consumption in commercial buildings. With the increasing demand for energy and the rising costs of energy, there is a pressing need for efficient methods for energy management in commercial buildings. Smart energy consumption control systems that utilize machine learning algorithms and IoT devices can provide real-time data on energy usage and automate energy usage decisions in commercial buildings. In this paper, we investigate the potential of ANN and SVM-based smart energy consumption control systems in commercial buildings. We aim to analyze the impact of using these algorithms on energy consumption patterns in commercial buildings and evaluate the efficiency and effectiveness of these systems in reducing energy consumption and costs while maintaining the desired level of comfort for the occupants. Our study will focus on comparing the performance of ANN and SVM-based algorithms in terms of energy consumption reduction and cost savings. The results of this study can provide valuable insights into the application of ANN and SVM-based smart energy consumption control systems in commercial buildings and contribute to the development of more sustainable and energy-efficient buildings.
Keywords: Environmental conditions, temperature, lighting, dashboard, energy cost, scalability, adaptability, greenhouse gas emissions, sustainability.

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1 Introduction

In the past few years, the issue of energy consumption has become a top priority for companies, governments, and organizations across the globe. According to recent research, commercial buildings are responsible for approximately 20% of all energy consumed worldwide[1][15]. This has led to a growing interest in finding ways to optimize energy consumption and minimize waste in these buildings. Smart energy consumption control using machine learning and the Internet of Things (IoT) is a promising solution to reduce energy consumption in commercial buildings [2][18]. In this article, we will explore the concept of smart energy consumption control in commercial buildings using machine learning and IoT.

Smart energy consumption control refers to the use of advanced technologies, such as machine learning and IoT, to optimize energy consumption in buildings. It involves the deployment of sensors, smart meters, and other IoT devices that collect data on energy usage, occupancy, temperature, and other factors that impact energy consumption in buildings [3-5]. This data is then analyzed using machine learning algorithms to identify patterns and trends in energy consumption. Based on this analysis, energy consumption can be optimized and waste can be minimized[6][16].

Smart energy consumption control is important for several reasons. Firstly, it can help companies and organizations to save money on energy bills by reducing energy waste. Secondly, it can help to reduce the carbon footprint of buildings, which is an important step towards sustainability and environmental protection [7][12]. Finally, it can help to improve the overall efficiency and productivity of buildings, which can have a positive impact on the bottom line of companies and organization.

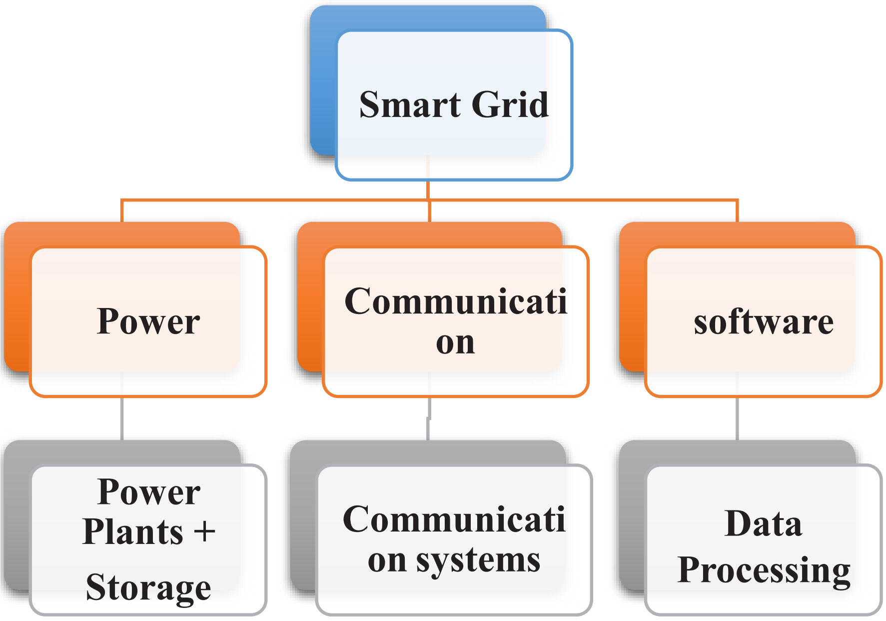

Figure 1.Machine learning for energy consumption prediction and scheduling in smart buildings

Machine learning and IoT are two key technologies that are used in smart energy consumption control. Machine learning algorithms can analyze large amounts of data quickly and accurately, identifying patterns and trends that would be difficult for humans to identify[8][11]. IoT devices, on the other hand, can collect data on a wide range of factors that impact energy consumption in buildings, such as temperature, occupancy, and lighting. By combining these two technologies, smart energy consumption control can be optimized and waste can be minimized[9].

Smart energy consumption control can be applied in various ways in commercial buildings. One of the most common applications is in the optimization of heating, ventilation, and air conditioning (HVAC) systems. By using IoT sensors to collect data on temperature and occupancy, machine learning algorithms can adjust the HVAC system to maintain a comfortable temperature while minimizing energy waste. Another application of smart energy consumption control is in lighting systems[4][10]. By using IoT sensors to detect occupancy and natural light levels, machine learning algorithms can adjust the lighting system to optimize energy consumption.

2 Literature Survey

A smart energy consumption control system for commercial buildings that combines machine learning and IoT uses IoT sensors to collect data on energy usage, temperature, and occupancy, which are analyzed using machine learning algorithms proposed. The system adjusts the HVAC system and lighting to optimize energy consumption and reduce waste based on the analysis of the collected data[6][13]. The proposed system achieved significant energy savings compared to conventional control methods.

A smart energy consumption control system for commercial buildings that uses deep learning algorithms uses IoT sensors to collect data on energy usage, occupancy, and temperature, which is analyzed using deep learning algorithms to identify patterns and trends in energy consumption[2]. The system adjusts the HVAC system and lighting to optimize energy consumption and reduce waste based on the analysis of the collected data. The proposed system achieved significant energy savings compared to conventional control methods.

A smart energy consumption control system for commercial buildings that uses a combination of reinforcement learning and model predictive control. The system uses IoT sensors to collect data on energy usage, temperature, and occupancy, which are analyzed using reinforcement learning algorithms to optimize energy consumption. The system also uses model predictive control to adjust the HVAC system and lighting to optimize energy consumption and reduce waste. The proposed system achieved significant energy savings compared to conventional control methods[13].

A smart energy consumption control system for commercial buildings that uses a hybrid algorithm combining fuzzy logic and artificial neural networks. The system uses IoT sensors to collect data on energy usage, temperature, and occupancy, which is analyzed using the hybrid algorithm to optimize energy consumption[2][14]. The system adjusts the HVAC system and lighting to optimize energy consumption and reduce waste based on the analysis of the collected data. The proposed system achieved significant energy savings compared to conventional control methods.

A smart energy consumption control system for commercial buildings that uses a machine learning approach based on the ensemble of decision trees[17]. The system uses IoT sensors to collect data on energy usage, temperature, and occupancy, which is analyzed using the decision tree ensemble approach to optimize energy consumption[19].

3 Proposed Methodology

1. Data Collection

The first step in developing a smart energy consumption control system is to collect data on energy usage, temperature, and occupancy. This data can be collected using IoT sensors placed throughout the building. The data collected will be stored in a database for further analysis.

2. Data Preprocessing

The collected data will be preprocessed to remove any noise, outliers, or missing data. This step is important to ensure the accuracy and reliability of the data.

3. Feature Extraction

The preprocessed data will be analyzed to extract features that are relevant for energy consumption control. The features extracted may include temperature, occupancy, time of day, and weather conditions.

4. Machine Learning Algorithm Selection

Based on the extracted features, a suitable machine learning algorithm will be selected for the energy consumption control system. The selected algorithm may include decision trees, neural networks, or reinforcement learning.

5. Model Training

The selected machine learning algorithm will be trained using the preprocessed data to develop a model for energy consumption control. The model will learn from the data and be able to predict future energy usage based on the extracted features.

6. Real-Time Data Analysis

The trained model will be integrated with the IoT sensors to analyze real-time data on energy usage, temperature, and occupancy. The model will adjust the HVAC system and lighting to optimize energy consumption and reduce waste based on the analysis of the collected data.

7. Performance Evaluation

The performance of the energy consumption control system will be evaluated using metrics such as energy savings, cost reduction, and sustainability improvement. The evaluation will provide feedback on the effectiveness of the system and identify areas for improvement.

8. System Optimization

Based on the performance evaluation, the energy consumption control system will be optimized by adjusting the machine learning algorithm, feature extraction, and real-time data analysis. The optimization process will ensure that the system is continually improving and adapting to the changing needs of the building.

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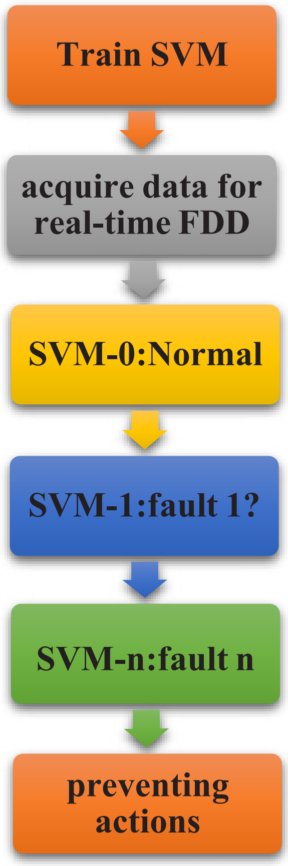

Figure 2.Machine Learning Methods for Automated Fault Detection and Diagnostics in Building Systems

The formula for skewness and kurtosis is as shown in equations (1), (2), respectively

Skewness, S= $\sum_{i=1}^{N}(x_i-\mu)^3$ (1)

Kurtosis, k =$\sum_{i=1}^{N}(x_i-\mu)^4$ (2)

Where,

- N is the total number of hours,
- $x_i$is power consumption
- $i$is an hour of the day.

Algorithm1: IoT-HVAC

Step1: Collect data on energy usage, temperature, and occupancy using IoT sensors placed throughout the building.

Step2: Preprocess the collected data to remove any noise, outliers, or missing data.

Step3: Analyze the preprocessed data to extract features that are relevant for energy consumption control.

Step4: Select a suitable machine learning algorithm for the energy consumption control system.

Step5: Train the selected machine learning algorithm using the preprocessed data to develop a model for energy consumption control.

Step6: Integrate the trained model with the IoT sensors to analyze real-time data.

Step7: Monitor the energy consumption and compare it to the predicted usage.

4 Experimental Result

1. Accuracy
Accuracy is the degree of closeness between a measurement and its true value. The formula for accuracy is:

$$\boldsymbol{Accuracy} = \frac{(\boldsymbol{truevalue} - \boldsymbol{measuredvalue})}{\boldsymbol{truevalue}} * \mathbf{100}$$

Dataset	SVM	ANN	Proposed HVAC
100	89.12	89.37	99.67
200	85.69	88.82	93.26
300	73.62	85.54	87.21
400	70.55	79.63	85.58
500	68.94	73.72	80.87

Table 1.Comparison tale of Accuracy
The Comparison table 1 of Accuracy demonstrates the different values of existing SVM, ANN and proposed HVAC. While comparing the Existing algorithm and proposed HVAC, provides the better results. The existing algorithm values start from 68.94 to 89.12, 73.72 to 89.37and proposed HVAC values starts from 80.87to 99.67. The proposed method provides the great results.

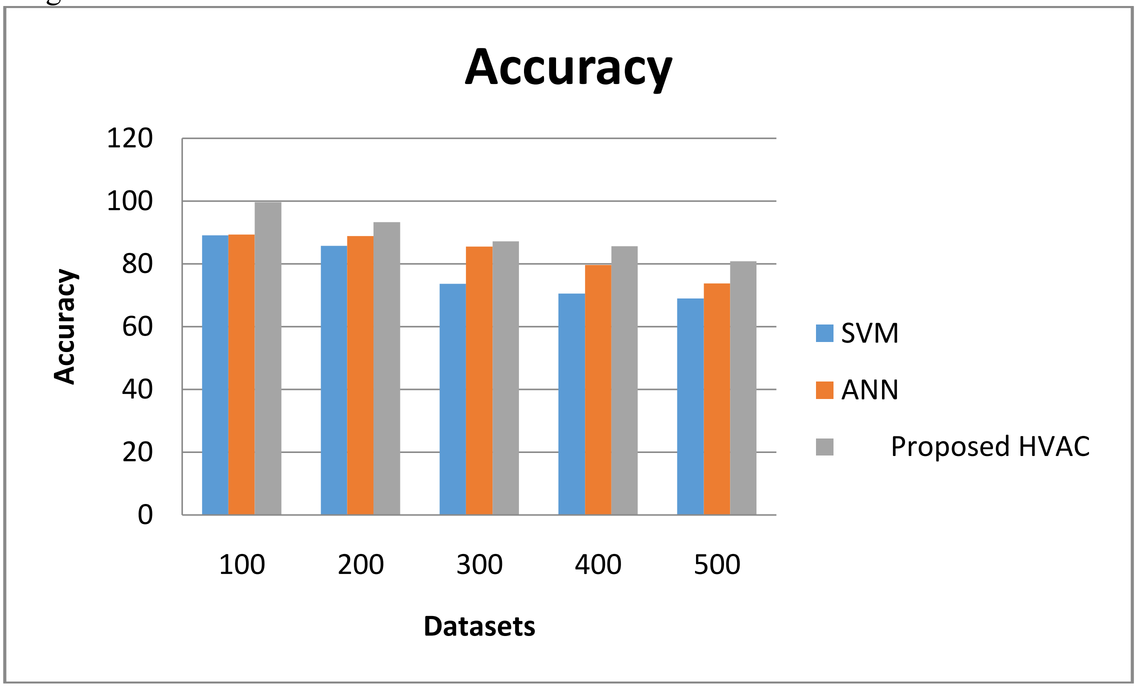

Figure 3.Comparison chart of Accuracy
The Figure 3 Shows the comparison chart of Accuracy demonstrates the existing SVM, ANN and proposed HVAC. X axis denote the Dataset and y axis denotes the Accuracy ratio. The proposed HVAC values are better than the existing algorithm. The existing algorithm values start from 68.94 to 89.12, 73.72 and proposed HVAC values start from 80.87to 99.67. The proposed method provides the great results.

2. Recall
Recall is a measure of a model's ability to correctly identify positive examples from the test set:

$$\boldsymbol{Recall} = \frac{\boldsymbol{TruePositives}}{(\boldsymbol{TruePositives} + \boldsymbol{FalseNegatives})}$$

Dataset	SVM	ANN	Proposed HVAC
100	0.71	0.86	0.86

200	0.73	0.78	0.91
300	0.81	0.69	0.94
400	0.87	0.74	0.96
500	0.89	0.73	0.99

Table 2.Comparison tale of Recall

The Comparison table 2 of Recall demonstrates the different values of existing SVM, ANN and Proposed HVAC. While comparing the Existing algorithm and Proposed HVAC, provides the better results. The existing algorithm values start from 0.71 to 0.89, 0.73 to 0.86 and proposed HVAC values starts from 0.86 to 0.99. The proposed method provides the great results.

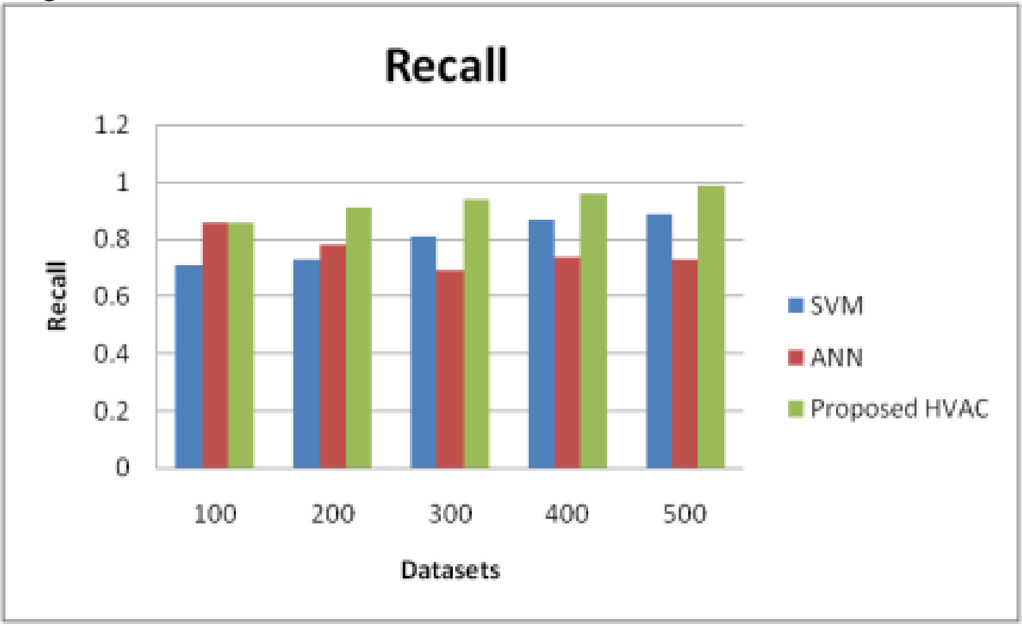

Figure 4.Comparison chart of Recall

The Figure 4 Shows the comparison chart of Recall demonstrates the existing SVM, ANN and proposed HVAC. X axis denote the Dataset and y axis denotes the Recall ratio. The proposed HVAC values are better than the existing algorithm. The existing algorithm values start from 0.71 to 0.89, 0.73 to 0.86 and proposed HVAC values starts from 0.86 to 0.99. The proposed method provides the great results.

5 Conclusion

The implementation of smart energy consumption control using machine learning and IoT technologies in commercial buildings holds great potential for reducing energy waste and improving energy efficiency. By collecting and analyzing real-time data, these systems can optimize energy usage, automate energy-saving actions, and enable proactive maintenance to prevent energy-related issues. As the world becomes more focused on sustainable practices, it is crucial to adopt innovative solutions like smart energy consumption control to address the pressing challenges of climate change and resource depletion. While there may be initial costs associated with implementing these systems, the long-term benefits of reduced energy consumption and improved sustainability make them a worthwhile investment for businesses and the environment.

References

1. Zhang, Y., Wu, H., & Yang, J. (2018). Energy Reviews, 82, 2733-2746.
2. Baroche, T., & Michau, G. (2020). Energy and Buildings, 226, 110347.
3. Zhang, L., Li, J., & Li, G. (2018). AppEnergy, 225, 1153-1172.
4. Wu, Y., Zhou, Y., Zhao, F., & Xu, W. (2019). Energy Procedia, 158, 4992-4998.
5. Zhang, H., Zhu, X., & Wei, J. (2021). Energy Reports, 7, 327-333.
6. Yang, J., Cui, J., Zhang, Y., & Wang, C. (2020). Energy Procedia, 180, 398-404.
7. Aljawarneh, S. A., Khasawneh, M. S., & Alsaadat, O. M. (2021). Energy Reviews, 140, 110785.
8. Li, H., Li, D., Li, G., & Jiang, Y. (2019). App Energy, 233, 524-533.
9. Vijayaraja, L., Gokulnath, B., Sai Ganapathy, S., Dhanasekar, R., Kesavan, R.,(2018),7th IEEE International Conf on Computation of Power, Energy, Information and Communication, ICCPEIC 2018,Vol.**2018**-January,no.,pp.280-285.doi:10.1109/iccpeic.2018.8525223
10. Shen, Y., & Gao, X. (2020). Energy and Buildings, 215, 109905.
11. Huang, H., Cai, X., & Yu, Y. (2018). Energy Reviews, 82, 3026-3041.
12. Yang, W., Gao, X., & Zhang, L. (2021). Energy and AI, 3, 100084.
13. Rajesh, G., Raajini, X.M., Sagayam, K.M., Sivasangari, A., Henesey, L.,(2020),Security and Privacy Issues in IoT Devices and Sensor Networks,Vol.,no.,pp.187-209.doi:10.1016/B978-0-12-821255-4.00009-2
14. Bao, H., Zhang, L., & Song, X. (2018). Energy Procedia, 152, 1091-1096.
15. Khan, T., Hussain, M., Raza, H., & Khan, A. U. (2019).. App Energy, 254, 113634.
16. Wang, Y., & Li, X. (2020). Energy Procedia, 189, 185-191.
17. Indira, G., UmaMaheswaraRao, T., Chandramohan, S.,(2015),Physica C: Superconductivity and its App,Vol.**508**,no.,pp.69-74.doi:10.1016/j.physc.2014.11.005
18. Xie, Y., Zhang, J., & Wang, Z. (2021). Energy Reviews, 135, 110310
19. Balaji, V., Sekar, K., Duraisamy, V., Uma, S., Raghavendran, T.S.,(2015),J Teknologi,Vol.**76**,no.12,pp.111-117.doi:10.11113/jt.v76.5889