

# Energy-efficient HVAC System with Decision Tree Classifier and Real-time SMS Notification

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## Abstract

*This research paper explores the design and implementation of an energy-efficient heating, ventilation, and air conditioning (HVAC) system aimed at optimizing energy consumption and enhancing operational efficiency. The system incorporates high-efficiency components, including axial flow fans, motors, and intelligent variable frequency drives, achieving an overall system efficiency of up to 85%. By utilizing both static and dynamic pressures, the HVAC system operates more effectively under varying conditions compared to traditional systems, which primarily rely on static pressure measurements. To further improve system responsiveness, a decision tree classifier is employed to predict the appropriate operational actions based on real-time temperature and slope data. This machine learning approach allows for proactive adjustments to the system's operation, enhancing its adaptability to changing environmental conditions. The classifier's performance is evaluated using accuracy, precision, and recall metrics, with results indicating a balanced performance, although with identified areas for improvement. In addition, a real-time SMS notification system is integrated using Twilio, which alerts facility management when the temperature exceeds a threshold of 28 degrees Celsius. This feature guarantees immediate notification about possible problems, enabling rapid intervention. The findings of this study underscore the significant potential of combining energy-efficient technologies with advanced machine learning algorithms in HVAC systems. The findings show that this sort of linkages can result in significant energy savings, enhanced efficiency in operation, and improved safety protocols. Future work will focus on expanding the dataset for the decision tree model and refining its parameters to enhance predictive accuracy, paving the way for more effective energy management solutions in HVAC applications.*

**Keywords:** Decision tree classifier, Energy efficiency, HVAC, Smart building technologies, SMS notifications

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## INTRODUCTION

The growing demand for energy-efficient building systems has led to significant advancements in Heating, Ventilation, and Air Conditioning (HVAC) technologies. HVAC systems play a critical role in ensuring comfort and air quality within indoor environments, but they are also among the largest consumers of energy in commercial and residential buildings. Therefore, keeping occupant comfort while lowering energy use and greenhouse gas emissions needs improving HVAC performance.

Recent innovations have highlighted the potential of intelligent systems, including machine learning algorithms and predictive analytics, to enhance

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HVAC efficiency. By leveraging data-driven approaches, facility managers can make informed decisions that optimize energy use, minimize operational costs, and reduce environmental impacts. For example, decision tree classifiers can be employed to predict and adjust HVAC operations based on real-time environmental variables such as temperature, humidity, and occupancy patterns. This adaptive control mechanism enables HVAC systems to respond dynamically to changing conditions, enhancing their efficiency and effectiveness [1].

Real-time control and observation are further made possible by the incorporation of IoT (Internet of Things) gadgets into HVAC systems.

IoT sensors collect data on various parameters, which can be analyzed to inform maintenance schedules, detect anomalies, and implement proactive measures to avoid system failures. Additionally, communication platforms such as Twilio can provide timely notifications regarding system performance, allowing for prompt interventions when necessary.

This paper presents a comprehensive overview of an energy-efficient HVAC system design that incorporates advanced components and intelligent control strategies. To maximize usage of energy, the system makes use of variable frequency drives (VFDs), high-efficiency fans, and engines.

Furthermore, the implementation of a decision tree classifier is explored to predict actions based on environmental data, while the use of SMS notifications ensures timely alerts for abnormal conditions. By examining the performance metrics of the proposed system, this research aims to demonstrate the benefits of integrating machine learning and IoT technologies into HVAC operations, highlighting the potential for substantial energy savings and improved system reliability [2].

## **METHODOLOGY**

### **System Design**

The HVAC system incorporates high-efficiency components, including axial flow fans (90% efficiency), motors (91% efficiency), and intelligent variable frequency drives (98% efficiency). These components are designed to work efficiently under varying static head conditions, providing flexibility and improved energy performance. The system's configuration also includes flame-proof features to enhance safety during operation.

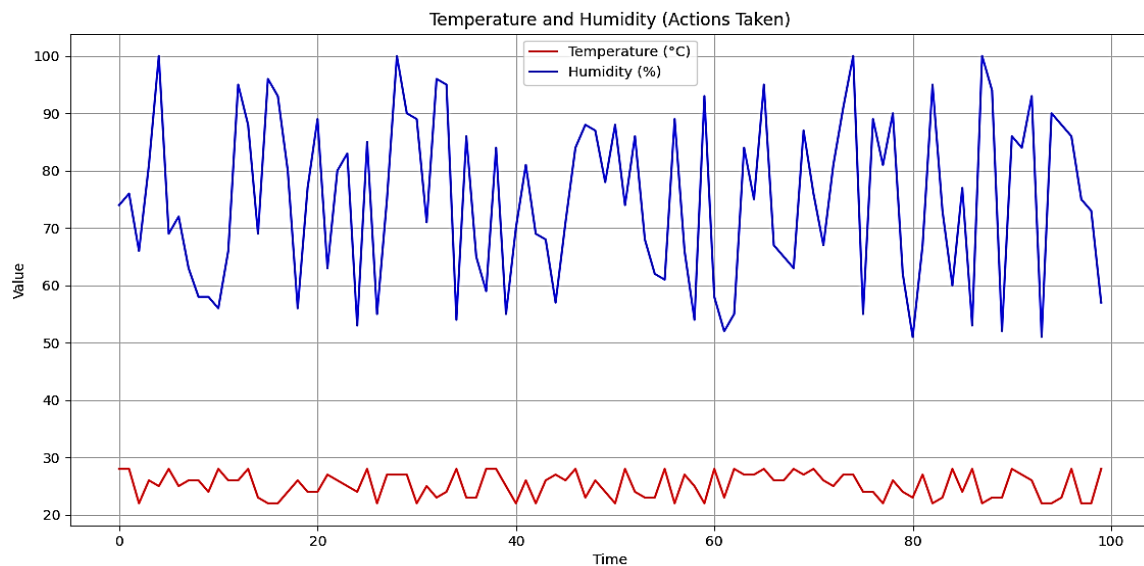
### **Decision Tree Classifier**

A decision tree classifier is trained to predict the appropriate actions based on the collected temperature and slope data. The dataset used for training includes labeled instances representing various operational states. The scikit-learn package is used to create the classifier, and measures like accuracy, precision, and recall are employed for evaluating its performance.

### **Real-Time SMS Notification System**

To facilitate immediate responses to environmental changes, an SMS notification system is integrated using Twilio. The system is programmed to send alerts when the temperature exceeds a predetermined threshold of 28 degrees Celsius. To guarantee effective collaboration, the SMS service makes contact with recipient phone numbers and credentials for accounts [3].

Overall, both the dispersion graph and the temperature and humidity graph play crucial roles in understanding the dataset and the results of the decision tree classifier. The dispersion graph provides an overview of the class distribution, while the temperature and humidity graph help analyse the relationship between these variables and the actions taken. These visual representations aid in interpreting the classifier's performance, identifying potential patterns or anomalies in the data, and gaining a deeper understanding of the underlying factors influencing the decision-making process (Figure 1).



**Figure 1.** Represent the temperature and humidity after implementing model.

## RESULTS AND DISCUSSION

The confusion matrix is a powerful tool to assess the performance of a decision tree classifier by comparing its predicted classes against the actual classes in the dataset. The genuine classes can be seen by each row in the matrix, while the anticipated classes are represented by all of the columns. The values in the matrix indicate how many instances of a certain actual class were misclassified into other expected classes (false positives) or appropriately predicted (true positives) [4].

Analyzing the confusion matrix allows us to evaluate the classifier's accuracy and effectiveness in correctly predicting each class. The classifier is doing excellent at accurately detecting instances of both positive and negative subclasses when the true positives and true negatives are both substantially higher.

A high number of true positives implies that the classifier is effectively capturing instances of the positive class, while a high number of true negatives indicates successful identification of instances of the negative class. This suggests that the classifier is well-balanced and can accurately distinguish between both classes. The confusion matrix can be evaluated to learn more about the classifier's positive and negative aspects.

**Table 1.** Represents the confusion matrix along with true positives and true negatives

S./N.	Action	True Positives	True Negatives
1	No action required for the gateway	10	75
2	Increase frequency by 0.5 Hz	7	69
3	Increase frequency by 1 Hz	7	61
4	Increase frequency by 2 Hz	7	58
5	No action required for the gateway	5	60
6	Decrease frequency by 0.5 Hz	4	61
7	Decrease frequency by 1 Hz	5	71
8	Decrease frequency by 2 Hz	3	80
9	No action required for the gateway	4	89

For instance, if there are relatively fewer true positives and more false negatives, it suggests that the classifier struggles to identify positive class instances, possibly due to class imbalance or lack of sensitivity to positive class patterns. In summary, the confusion matrix indicated in Table 1 provides a comprehensive view of the classifier's performance on different classes, enabling us to evaluate its overall accuracy and identify specific areas of improvement. When true positives and true negatives are

relatively high, Table indicates that the classifier is performing relatively better, achieving a good balance in correctly classifying instances of both positive and negative classes [5].

The overall correctness of the classifier's predictions can be assessed by the accuracy score. To evaluate the classifier's overall sensitivity and accuracy in identifying positive incidents precision and recall scores are computed. To give a comprehensive picture of the classifier's performance, a confusion matrix is created that displays the numbers of genuine positives, genuine negatives, false positives, and false negatives.

### The Table 2 shows the Accuracy, Precision and Recall

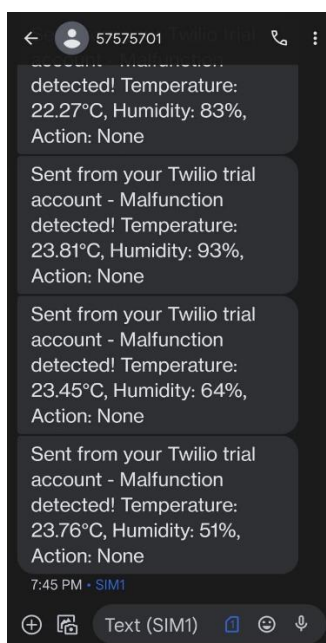
The accuracy score, precision score, recall score, and confusion matrix collectively provide insights into the performance of the decision tree classifier. These metrics enable us to evaluate the effectiveness and reliability of the classifier in predicting the classes of the dataset [6].

**Table 2.** Accuracy, precision, recall, and confusion matrix achieved from the model.

Accuracy	0.68
Precision	0.634
Recall	0.52

### Impact of SMS Notification System

In our project, we have implemented an SMS notification system using Twilio to send real-time alerts when the temperature surpasses 28 degrees Celsius. The Twilio service is integrated into the code, utilizing the account SID, authentication token, and phone numbers specified in the variables. The logic for sending SMS notifications is implemented within a loop that iterates through each data point in the dataset. For each data point, the code checks if the temperature exceeds the threshold of 28 degrees Celsius [7]. If it does, an SMS message is composed with the current temperature information, notifying the recipient about the abnormal temperature condition. The Twilio client is then used to send the SMS message to the specified recipient's phone number. By employing this approach, we ensure that facility control is promptly alerted whenever the AHU's temperature goes beyond the acceptable range [8–10]. This real-time alerting system enables facility management to take immediate action to address any malfunctioning or potential issues with the AHU, helping maintain a safe and efficient environment within the facility (Figure 2).



**Figure 2.** SMS notification from the Twilio account whenever there is malfunctioning.

## CONCLUSION

The energy-efficient HVAC system described in the concept offers significant advantages in terms of efficiency and energy savings. It consists of high-efficiency components such as fans (90% efficiency), motors (91% efficiency), and intelligent variable frequency drives (98% efficiency). The system is flame-proof and built for operation well even at deeper static heads.

Compared to traditional HVAC systems that rely solely on static pressure, this system utilizes both static and dynamic pressures, resulting in efficiencies above 90%.

Axial flow fans are preferred over plug and centrifugal fans due to their ability to utilize both static and dynamic pressures, making them more energy-efficient and cost-effective in the long run. The overall system efficiency, including fans, motors, and frequency drives, reaches an impressive 85%, surpassing alternative solutions in the market. Depending on the type of fan substituted, the system's potential energy savings may range from 20% to 50%.

The system has a long lifetime of 20 years, low maintenance costs, and minimal sound levels. Additionally, it is made so it can easily installed in systems where it already exist.

Overall, this energy-efficient HVAC system offers substantial energy savings, improved efficiency, and cost-effective operation. The project involves training a decision tree classifier to predict the appropriate action based on temperature and slope. The class labels and corresponding actions are defined in a dictionary. The classifier is trained using the provided dataset, and the predicted classes and actions are added to the Data Frame.

The work includes functionality to send an SMS notification if the temperature exceeds a certain threshold, utilizing Twilio for communication. To assess the classifier's forecasting, performance metrics including accuracy, precision, recall, and the confusion matrix are computed.

The decision tree is visualized using the plot tree function from scikit-learn. Additionally, a graph is created to display the temperature and humidity values for the actions taken.

The Data Frame is subsequently copied to an Excel document for further investigation.

Although the dataset used in this project is limited in size, resulting in reduced accuracy, the decision tree model remains a promising approach for energy efficiency control. To improve the model's performance, future implementations should consider using a larger and more representative dataset, along with fine-tuning the model's parameters. Other factors like data quality, feature engineering, and model selection should also be considered for enhancing the overall system performance.

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