

HVAC Optimization in Labs

Overview

HVAC Optimization in Labs is a smart energy management project that predicts cooling requirements in laboratory spaces using occupancy and temperature sensor data. A Decision Tree model is used to forecast cooling needs, and the results are visualized through a zone-wise heatmap on a Streamlit dashboard to support efficient HVAC operation.

Problem Statement

Laboratory HVAC systems often run at full capacity even when rooms are partially occupied or empty, leading to energy wastage. The objective is to predict cooling demand based on temperature and occupancy so that HVAC systems can operate at optimal levels and reduce unnecessary energy consumption.

Dataset

The project uses a Room Occupancy sensor dataset containing Date, Time, multiple temperature sensors (S1_Temp–S4_Temp), CO₂, light, sound, PIR motion, and Room_Occupancy_Count. Average room temperature is computed from multiple sensors to represent actual lab conditions.

Workflow

Load the dataset and clean column names. Combine Date and Time into a timestamp. Compute average temperature from multiple sensors. Select average temperature and occupancy as input features. Create cooling requirement labels (Low, Medium, High) based on temperature and occupancy thresholds. Train a Decision Tree classifier to learn cooling patterns. Predict cooling requirements for recent data. Group records into temperature and occupancy zones and generate a heatmap showing zone-wise cooling demand.

Technologies Used

Python, Pandas, Scikit-learn (Decision Tree), Seaborn, Matplotlib, Streamlit.

Installation

Install dependencies using: pip install pandas scikit-learn seaborn matplotlib streamlit

How to Run

Place the room occupancy CSV file in the project directory and run: streamlit run app.py

Key Features

Predicts cooling needs using real sensor data, uses averaged temperature for realistic HVAC decisions, provides zone-wise visualization through heatmaps, and supports energy-efficient lab operation.

Applications

Smart campus energy management, automated HVAC control, laboratory facility optimization, and building management system integration.

Limitations

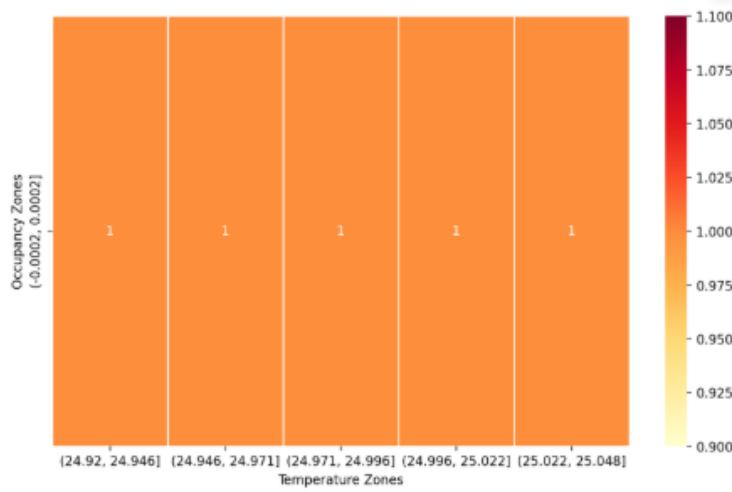
Cooling labels are rule-based, occupancy levels may be low in the dataset leading to uniform predictions, and external factors like humidity or equipment heat are not included.

Output

The dashboard displays a zone-wise heatmap where each cell represents the predicted cooling requirement based on temperature and occupancy ranges. Cooling levels are encoded as Low, Medium, or High to indicate HVAC demand intensity.

HVAC Optimization in Labs

Zone-wise Cooling Requirement Heatmap



Future Enhancements

Include additional environmental variables such as humidity and CO₂, use regression to estimate exact cooling load, integrate real-time IoT sensor streams, and enable automated HVAC control actions.

Conclusion

The project demonstrates that occupancy and temperature driven decision tree models can effectively estimate laboratory cooling requirements and visualize zone-wise demand, enabling intelligent and energy-efficient HVAC management.