High Level Design (HLD)

EcoComfort: Intelligent Energy Efficiency for Residential Buildings

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Contents

1. Introduction

1.1 Why this High-Level Design Document?

The purpose of this High-Level Design (HLD) Document is to add the necessary detail to the current project description to represent a suitable model for coding. This document is also intended to help detect contradictions prior to coding, and can be used as a reference manual for how the modules interact at a high level.

The HLD will:

- Present all of the design aspects and define them in detail
- Describe the user interface being implemented
- Describe the hardware and software interfaces
- Describe the performance requirements
- Include design features and the architecture of the project
- List and describe the non-functional attributes like:
    - Security
    - Reliability
    - Maintainability
    - Portability
    - Reusability
    - Application compatibility
    - Resource utilization
    - Serviceability

1.2 Scope

The HLD documentation presents the structure of the system, such as the database architecture, application architecture (layers), application flow (Navigation), and technology architecture. The HLD uses non-technical to mildly-technical terms which should be understandable to the administrators of the system.

1.3 Definitions

Term	Description
E-IEE	EcoComfort: Intelligent Energy Efficiency
IDE	Integrated Development Environment
DATABASE	Collection of all the information monitored by this system
GCP	Google Cloud Platform

2. General Description

2.1 Product Perspective

EcoComfort: Intelligent Energy Efficiency for Residential Buildings, model is a machine learning regression model. This project aims to leverage industrial automation techniques to enhance energy efficiency in residential buildings by accurately predicting the heating load and cooling load. The system, named "EcoComfort," combines advanced algorithms and data analysis to optimize HVAC systems, leading to improved comfort and reduced energy consumption.

HVAC stands for Heating, Ventilation, and Air Conditioning. An HVAC system refers to the equipment and infrastructure used in buildings to control and regulate indoor environmental conditions, including temperature, humidity, and air quality.

The heating component of an HVAC system is responsible for generating and distributing heat throughout a building, typically using methods such as furnaces, boilers, or heat pumps. It ensures that the indoor temperature remains comfortable during colder periods.

Ventilation is another critical aspect of an HVAC system. It involves the exchange of indoor and outdoor air to maintain proper air circulation, remove contaminants, and control humidity levels. Ventilation systems can include fans, ductwork, and air vents.

Air conditioning, the third component of an HVAC system, involves cooling and dehumidifying indoor air. Air conditioners use various methods, such as refrigeration cycles or evaporative cooling, to lower the temperature and remove excess moisture from the air.

2.2 Problem statement

Inefficient heating, ventilation, and air conditioning (HVAC) systems in residential buildings lead to excessive energy consumption and discomfort for occupants. The lack of accurate load predictions and suboptimal HVAC operations contribute to increased energy costs and environmental impact. There is a need for an industrial automation solution that accurately predicts heating and cooling loads, optimizing HVAC systems for improved energy efficiency and occupant comfort. The proposed "EcoComfort" system aims to address these challenges by combining advanced algorithms and data analysis to dynamically adjust HVAC operations based on real-time load requirements.

2.3 Proposed Solution

To enhance energy efficiency in residential buildings and accurately predict the heating load and cooling load, a machine learning regression model will be developed. The model will utilize comprehensive data on various measurements within the building to accurately estimate the specific heating and cooling requirements.
This approach will enable the optimization of HVAC systems to match the actual requirements, resulting in reduced energy waste and improved comfort levels for occupants.

2.4 Data Requirements

We will require the dataset having complete details of the different measurements of the building like 'relative compactness', 'surface area', 'wall area', 'roof area', 'overall height', 'orientation', glazing area', 'glazing area distribution', 'heating load (HL)', 'cooling load (CL)'.

2.5 Tools used

Python programming language and frameworks such as NumPy, Pandas, Scikit-learn, are used to build the whole model.

- VSCode is used as IDE.
- For visualization of the plots, Matplotlib, Seaborn and Plotly are used.
- GCP is used for deployment of the model.
- MySQL/MongoDB is used to retrieve, insert, delete, and update the database.
- Front end development is done using HTML/CSS
- Python Flask is used for backend development.
- GitHub is used as version control system.

2.5.1 Hardware Requirements

- PC (system with minimum i3 processor and 6GB ram).

2.6 Constraints

The E-IEE system must be user friendly, as automated as possible and users should not be required to know any of the workings.

2.7 Assumptions

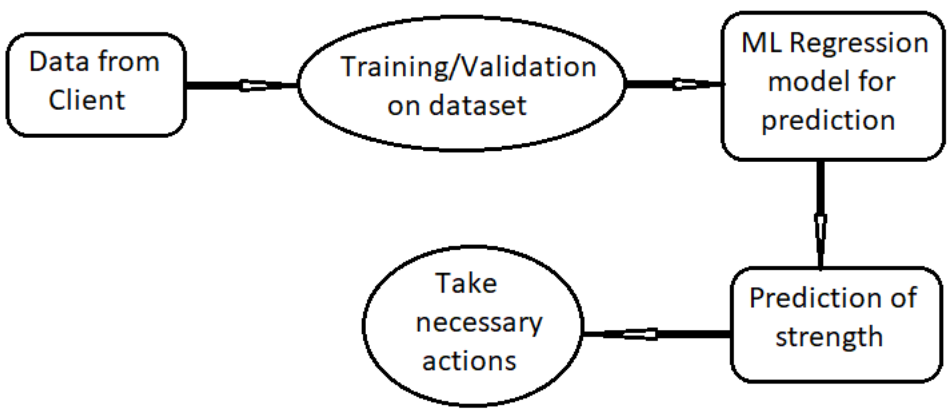
The main objective of the project is to implement the use cases as previously mentioned (2.2 Problem Statement) for new dataset that comes through client. Machine learnig model is used for predicting the above-mentioned use cases based on the input data. It is also assumed that all aspects of this project have the ability to work together in the way the designer is expecting.

3. Design Details

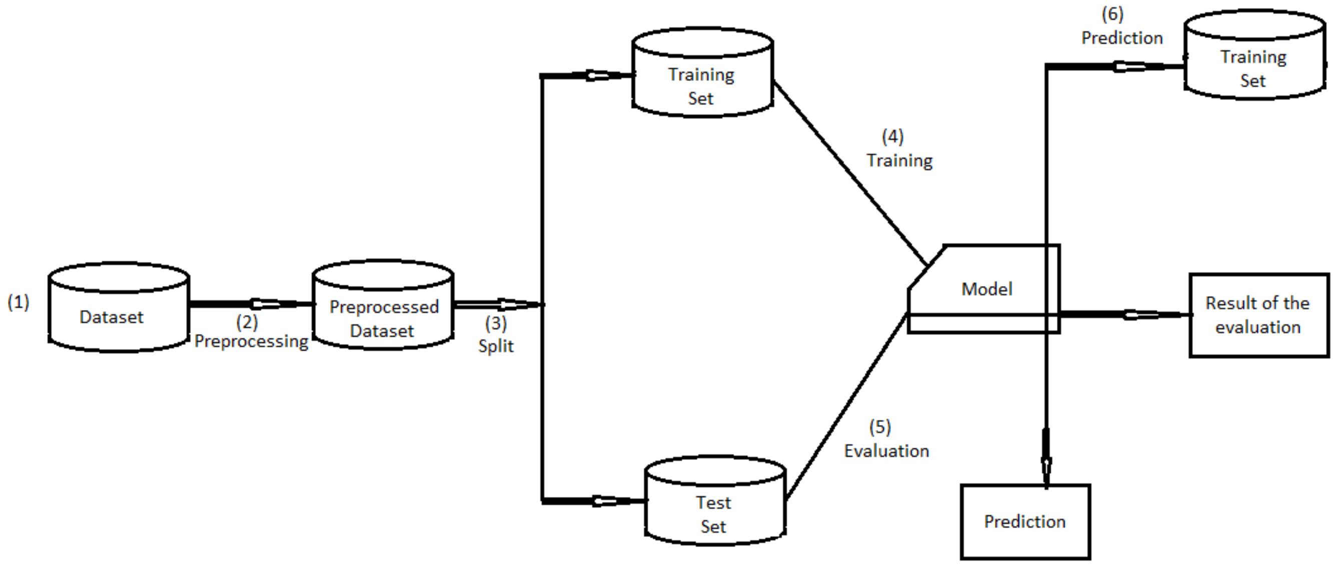
3.1 Process Flow

For predicting the the heating and cooling load, we will use a machine learning model.
Below is the process flow diagram.

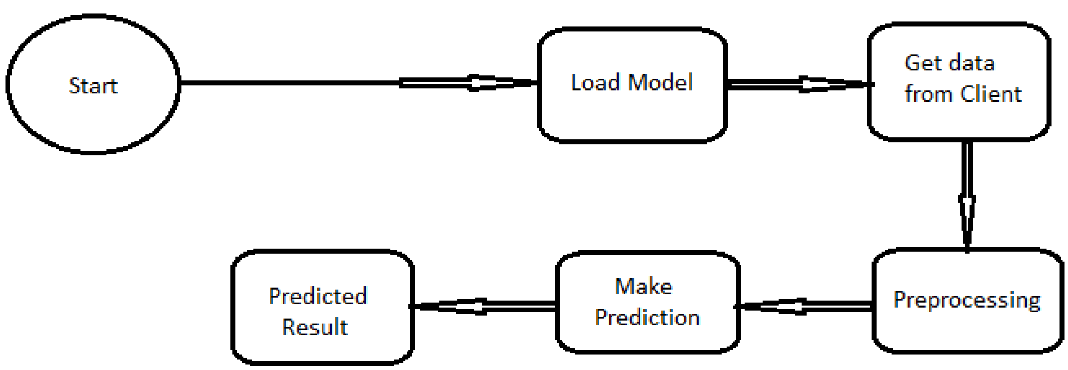
Proposed methodology



3.1.1 Model Training and Evaluation



3.1.2 Deployment Process



3.2 Event log

The system should log every event so that the user will know what process is running internally.

Initial Step-By-Step Description:

1. The System identifies at what step logging required
2. The System should be able to log each and every system flow.
3. Developer can choose logging method. He can also choose database logging/ File logging as well.
4. System should not hang even after using so many loggings. Logging is done so that we can easily debug issues. Therefore logging is mandatory to do.

3.3 Error Handling

Whenever any errors is encountered, an explanation will be displayed as to what went wrong? An error can be defined as anything that falls outside the normal and intended usage.

3.4 Performance

The E-IEE Model is used for predicting the heating load and cooling load. It will predict the heating load and cooling load after receiving prediction data and it should be as accurate as possible.
Also, model retraining is very important to improve the performance.

3.5 Reusability

The code written and the components used should have the ability to be reused with no problems

3.6 Application Compatibility

The different components for this project will be using Python as an interface between them. Each component will have its own task to perform, and it is the job of the Python to ensure proper transfer of information.

3.7 Resource Utilization

When any task is performed, it will likely use all the processing power available until that function is finished.

3.8 Deployment

4. Conclusion

In conclusion, the project "EcoComfort" has successfully demonstrated the potential of leveraging industrial automation techniques to enhance energy efficiency in residential buildings. By accurately predicting the heating load and cooling load, the system has effectively optimized HVAC systems, resulting in improved comfort levels for occupants and a significant reduction in energy consumption.

The impact of this project extends beyond energy savings. By reducing the overall energy consumption of residential buildings, "EcoComfort" contributes to environmental sustainability and helps mitigate the effects of climate change. It also offers financial benefits to homeowners and building operators by lowering energy bills and reducing the maintenance costs associated with HVAC systems.