High Level Design (HLD)

Energy Efficiency

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Contents

Abstract

We develop a statistical machine learning framework to know the effect of eight input variables (relative compactness, surface area, wall area, roof area, overall height, orientation, glazing area, glazing area distribution) on two output variables, namely heating load (HL) and cooling load (CL), of residential buildings. We systematically investigate the association strength of each input variable with each of the output variables using a variety of classical and non-parametric statistical analysis tools, in order to identify the most strongly related input variables. Then, we compare a classical linear regression approach against a powerful state of the art nonlinear non-parametric method, random forests, to estimate HL and CL. Extensive simulations on 768 diverse residential buildings show that we can predict HL and CL with low mean absolute error deviations from the ground truth which is established using Ecotect (0.51 and 1.42, respectively). The results of this work support the feasibility of using machine learning tools to estimate building parameters as a convenient and accurate approach, as long as the requested query bears resemblance to the data actually used to train the mathematical model in the first place.

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 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*
EE	Energy Efficiency
IDE	Integrated Development Environment
HL	Heating Load
CL	Cooling Load

2. General Description

2.1 Product Perspective

The Energy Efficiency system is a Machine Learning regression model which will help us to detect the Heating Load (HL) and Cooling Load (CL) of different residential building shapes simulated in Ecotect.

2.2 Problem Statement

To create an AI solution in order to predict the Heating Load (HL) and Cooling Load (CL) of 768 residential buildings which differ with respect to relative compactness, surface area, wall area, roof area, overall height, orientation, glazing area, glazing area distribution.

2.3 Proposed Solution

In order to solve the above multi-Regression problem we have applied various Regression Algorithms and have chosen the best performing Machine Learning model which predicts the Heating Load and Cooling Load with low mean absolute error deviations from the ground truth.

2.4 Data Requirements

The dataset required for the energy efficiency system has been taken from UCI Machine Learning Repository – Energy Efficiency Dataset.

2.5 Tools Used

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

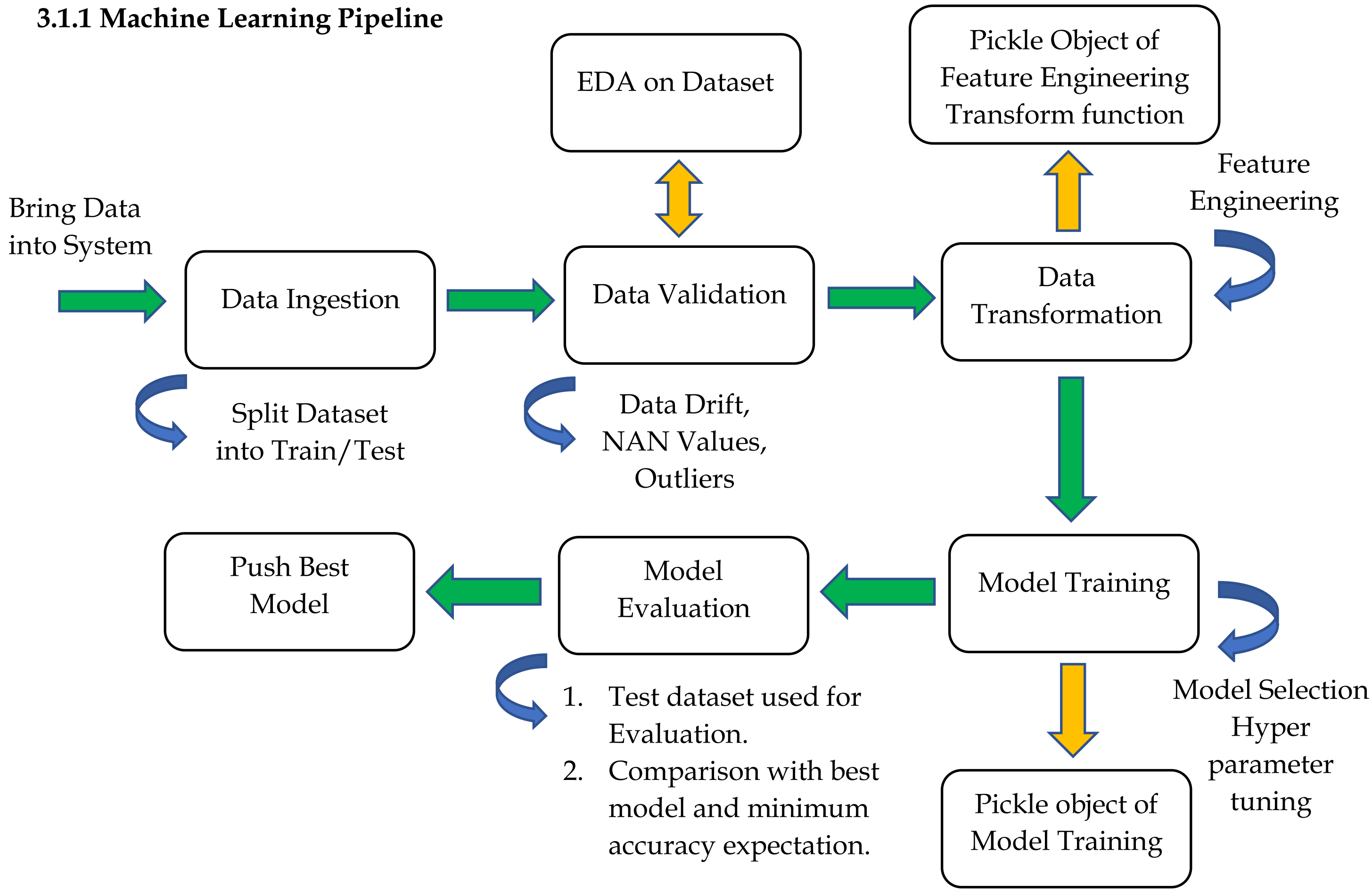
- VS Code is used as IDE.
- For visualization of the plots – Matplotlib, Seaborn is used.
- Front end development is done used HTML/CSS
- GitHub is used as version control system.

3. Design Details

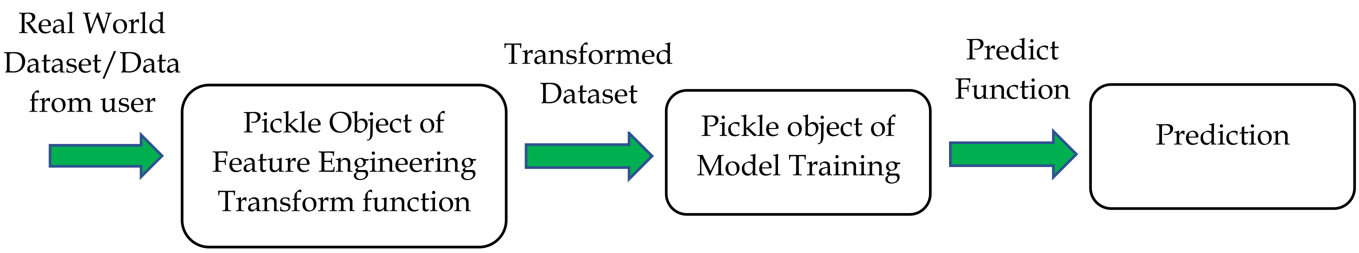
3.1 Process Flow

To predict the Heating Load (HL) and Cooling Load (CL) we will use a Machine Learning model. Below is the process flow diagram.

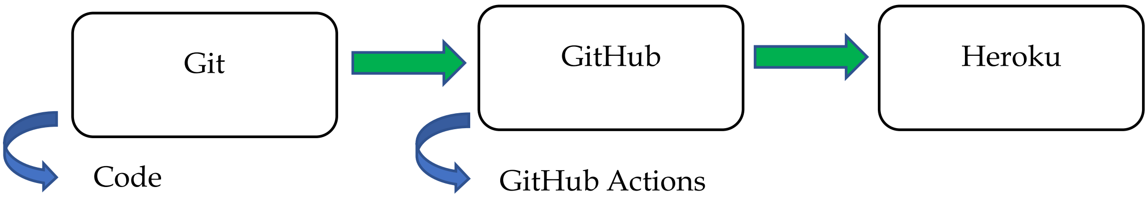
3.1.1 Machine Learning Pipeline



3.1.2 Prediction Pipeline



3.1.3 Deployment CICD Pipeline



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. You can choose database logging/ File logging as well.
4. System should not hang even after using so many loggings. Logging is just because we can easily debug issues so logging is mandatory to do.

3.3 Error & Exception Handling

Error & Exception handling implemented in order to encounter errors and provide an explanation/display as to what went wrong. An error will be defined as anything that falls outside the normal and intended usage.

3.4 Performance

The Energy Efficiency system is used for predicting the Heating Load (HL) and Cooling Load (CL) of the residential buildings, so it should be as accurate as possible.

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

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4. Conclusion

As the designed energy efficiency system accurately predicts the Heating Load (HL) and Cooling Load (CL) of the residential buildings based on the input variables provided - Hence it supports the feasibility of using machine learning algorithms to estimate building parameters as a convenient and accurate approach, as long as the requested query bears resemblance to the data actually used to train the mathematical model in the first place.

5. References

<u>Relevant Papers:</u>

A. Tsanas, A. Xifara: 'Accurate quantitative estimation of energy performance of residential buildings using statistical machine learning tools', Energy and Buildings, Vol. 49, pp. 560-567, 2012.