Estimation of thermal Comfort based on CO2 level

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Abstract

Air temperature and the Co2 level in a particular space play a vital role, it does not only affect energy consumption, but also occupancy, thermal discomfort, ventilation behaviour and building performance maintenance. The effect of air temperature and CO_2 level in the bedroom of the building is used to predict the thermal comfort of the room. The paper aims to build a prediction model for thermal discomfort based on the air temperature and the carbon dioxide level using a Linear Regression. The CO_2 level indoor environment ranges between 350 to 2500 ppm. It is important to maintain the level in the range, to have lower thermal discomfort. The occupancy in the room increases the air temperature, air circulation and CO_2 level of the room. To predict the CO_2 level in the bedroom using the external and the indoor temperature linear regression predictive model is used. The study measures the thermal discomfort level and helps the user to take action towards optimizing the air circulation and thermal comfort of the bedroom.

Keywords: Thermal comfort, Linear Regression, Carbon dioxide level, air temperature.

TABLE OF CONTENT

1. Introduction

Thermal Comfort is one of the major factors which affects the energy consumption of a particular building. Additionally, ventilation and thermal comfort completely depend upon the air temperature, CO2 level and occupancy. Ventilation is a reflection of thermal comfort, behavioural model and occupancy of the building. Therefore the thermal comfort model is modelled using machine learning algorithms.

The project is implemented on a smart home of 120 m^2 with 5 people living. The home has 340 measuring points, parameters measured are temperature, humidity, light state, brightness, gas, Co2 level, water consumption, Energy Consumption, air flow, window state, and movement of people inside the house.

Figure 1 : Smart Home

The approach is data-driven, the data which influence the window opening such as rain, wind, light and temperature are collected from the Raspberry pi controller. The collected data is cleaned and analysed and all the datasets are concatenated into one dataset.

The report focuses on designing a model for ventilation and thermal comfort in the bedroom using a decision tree. The model is trained and tested with the data collected from the sensors using a controller.

Figure 2 : Sensor found in the Platform

2. Thermal Comfort

Thermal comfort is a level of comfort that is neither cold nor hot feeling human experiences in the room. When the air temperature, humidity, air circulation and carbon dioxide level are at good levels, then the thermal comfort of the room is high. In a room the heat exchange from the body to the indoor environment takes place in 3 processes: Evaporation, Conduction and Radiation through respiration, body temperature and other activities.

2.1 Factors Affecting ventilation Behaviour and thermal comfort

Indoor and Outdoor Temperature

Temperature and humidity have an inverse pattern. When the temperature increases there is a significant decrease in moisture. Any change in the outdoor temperature causes an impact on the indoor temperature. The temperature has a seasonal pattern for instance high temperature during the summer season and low temperature during the winter season. The intensity of indoor temperature is always higher than the intensity of outdoor temperature, as the indoor temperature can be adjusted by electrical equipment such as air conditioning, heaters and lighting. (Ayanlade et al., 2019)

Carbon dioxide level and Occupancy

Carbon dioxide naturally affects ventilation behaviour, as indoor CO_2 level increases as human respiration. High levels of CO_2 imply poor air circulation in the given indoor space. When there is a high number of people in the indoor space the CO_2 level increases and this leads to poor ventilation and thermal discomfort. (Abdullah & Alibaba, 2020)

3. Methodology

3.1 Data Collection

The ventilation behaviour of the bedroom in the smart room is studied by collecting data of outdoor temperature, indoor temperature, humidity, and CO_2. The smart home has 340 measuring points and all the messing points are controlled by Raspberry pi, the data was collected by connecting to the controller. The decision tree method was selected to approach and build the ventilation behaviour and thermal comfort model. The dataset is provided in CSV file format. The dataset collected is sampled to format the data at the same time.

Data Types of Measuring Points are:
Indoor Temperature: Float
Outdoor Temperature: Float
CO_2: Float

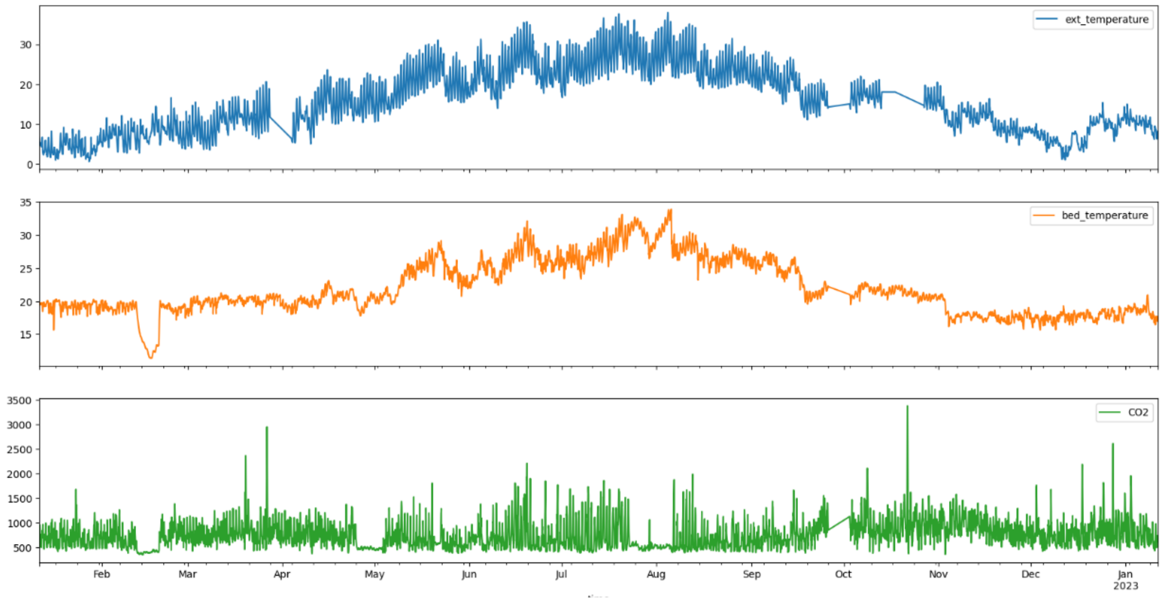

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Figure 3 : CO2 level, Indoor and External Temperature

3.2 Regression

Linear Regression

Linear regression is a type of predictive method. The variables to be predicted are the dependent variable and the variable used to predict the dependent variable is the independent variable. The method predicts by using the linear relationship between the dependent and independent variables. (Kanade, 2022) In our case, X is the dependent variable, which is external and indoor temperature whereas Y is the independent variable which is carbon dioxide level. The main aim of implementing linear regression is to achieve the best fit for the model.

Decision Tree

Decision tree Regression is implemented to estimate the thermal discomfort in the bedroom. A decision tree is a tool used to build a model for supervised learning, it is a flowchart-like structure. The Decision nodes are the conditions and the end nodes are the result. (Geeks For Geeks,2023).A regression decision tree predicts a continuous value rather than a discrete value. 70% of data from the collected dataset is used for training and the remaining 30% is used for testing the model.

R2 Score

R squared score is the ratio of the variation in the dependent variable [X] to the variation in the independent variable [Y]. R squared score is between 0 to 1. (Yse, 2020)

$$\text{R2 Score} = \frac{Variation\ in\ the\ dependent\ Variable}{Variation\ in\ the\ independent\ Variable}$$

R2 Score

```
from sklearn.metrics import r2_score
r2_score(Y_test,y_pred2)
```

```
-0.4802556523246124
```

Figure 4 : R2 Score

Mean Absolute Error [MAE]

Mean Absolute Error is the arithmetic difference between the actual value and the predicted value. (Padhma M, 2022)

$$\text{MAE} = \frac{1}{n} \sum_{i=1}^{n} | y_i - \hat{y}_i |$$

Mean absolute error

```
mse = metrics.mean_absolute_error(Y_test, y_pred2)
mse
```

```
217.4892706438538
```

Figure 5 : Mean Absolute Error

5. Result and Analysis

On Implementing linear regression, we got the graph with dependent variable in the X axis and independent variable in the Y axis. From the graph it is observed that carbon dioxide level increases on increase in the air temperature in the bedroom.

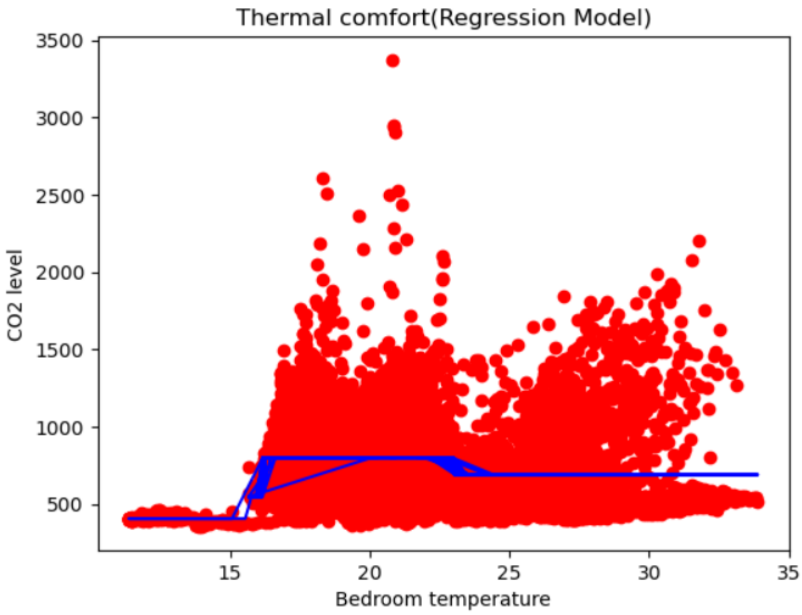

Figure 6 : Linear Regression

In figure 7, we tried to predict the carbon dioxide level by setting the external temperature as value 7 and indoor temperature as 19. The predicted output received is 1074.37 ppm and the value of CO_2 level is between the required range 350 to 2000 ppm.

```
predictCO2 = regr.predict([[7,19]])
predictCO2
```

```
array([[1074.37438288]])
```

Figure 7 : Linear Regression Prediction

Next prediction method implemented to predict carbon dioxide level is decision tree regression. The random state is set to decision tree prediction is 0 and the result we obtained on the decision tree is also in between the optimal range.

```
y_pred2= regressor2.predict(X_test)
y_pred2
```

```
array([ 583.        , 1163.5      ,  582.25     , ..., 1057.       ,
        492.28571429,  744.875     ])
```

Figure 8 : Decision Tree Prediction

The result obtained is optimal since the linear regression and the decision tree model is able to predict the carbon dioxide level between the nominal range.

6. Conclusion

In the project, the main goal was to design a predictive model for thermal comfort based on the external temperature and the indoor temperature of the bedroom. The air circulation and the occupancy can be improved from the result of the build model. The linear regression and decision tree regression are studied and the results obtained are between the limit expected which is 350- 2000 ppm. Furthermore the thermal comfort of other rooms, hallway and living space can be predicted by the improvement of the model. It is also understood that the thermal discomfort depends on the air temperature, humidity, occupancy and carbon dioxide level of the room.

7. Reference

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