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GitHub Link	*https://github.com/AjoobKansakar/AI_Coursework.git*

I confirm that I understand my coursework needs to be submitted online via MST Classroom under the relevant module page before the deadline for my assignment to be accepted and marked. I am fully aware that late submissions will be treated as non-submission and a mark of zero will be awarded.

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1. Introduction

1.1 Explanation of the Topic / AI Concepts Used

Artificial Intelligence (AI) is the capability of machines to simulate human intelligence, such as learning from data, and making predictions. One of the most widely used branches of Artificial Intelligence is Machine Learning (ML), it is a concept of AI where a system learns patterns from huge set of data and use them to make predictions on unseen data.

Machine Learning problems are mainly categorized into the following categories:

- Supervised learning
- Unsupervised learning
- Reinforcement learning

In this project, Supervised learning concepts are used where the model is trained using pre-labelled data meaning the data contains input features and a known output value.

Machine learning concepts used in this project is Regression which is used when the target variable is a continuous numerical value. The main objective of this project is to calculate the target variable calorie content (Energy in kcal), which is a continuous numerical value. Therefore, Regression was chosen for this project.

In order to predict calories based on nutritional information, the project uses the following regression algorithms:

- Linear Regression
- Decision Tree Regressor
- Random Forest Regressor

These algorithms study the relationship between nutritional attributes such as proteins, carbohydrates, and fats, and the corresponding calorie values.

1.2 Introduction of the Chosen Problem Domain

Nutrition plays a crucial role in maintaining a healthy lifestyle, and calorie estimation is one of the most important in health management, diet planning, and fitness tracking. Daily calorie intake directly affects one's body weight, energy levels, and overall health. This project was carried out to understand nutrition labels to calculate calorie intake as not all the food items consist of a nutrition label or accurate calorie information.

With the increasing availability of nutritional datasets, this project focuses on the development of a machine learning software that provides an effective solution to automatically predict calorie content based on known nutritional properties. By analyzing the relationship between macronutrients such as carbohydrates, proteins, and fats, it is possible to estimate calorie values with upmost accuracy.

The aim of the project is to predict the calorie content of food items using machine learning processes such as regression models trained on a real-world nutrition dataset. The project solution aims to demonstrate the use of artificial intelligence to assist in automating calorie estimation and support healthy lifestyle.

For this project, the dataset was obtained from Hugging Face:

https://huggingface.co/datasets/adarshzolekar/foods-nutrition-dataset

2. Background

2.1 Research Work Done in Coursework 1

During Coursework 1, many of the foundational machine learning concepts were studied which included data pre-processing, supervised learning, regression techniques, and model evaluation. During initial data exploration, several issues were identified and special priority was placed on understanding how regression models learn relationships between input variable and continuous output values.

After reviewing the dataset, concepts such as train-test splitting, feature normalization, and evaluation metrices like Mean Absolute Error (MAE), Root Mean Square (RMSE), and R2 score were introduced which forms the theoretical foundation for this project and are applied directly for predicting calorie values from nutritional dataset.

Several studies have been conducted for food analysis and calorie estimation using machine learning techniques like regression-based models that can effectively predict calorie values when trained on nutritional attributes like macronutrients and portion sizes. Some of the articles related to the issue is provided below:

1) Machine learning In Nutrition Research

This study provides a review of how machine learning techniques are used in nutrition research and also discusses the use of supervised learning models, including regression-based approaches, to analyse nutritional datasets. The article highlights that traditional methods of estimating calorie content struggles with complex nutrition data, whereas using the machine learning models are more effective in estimating the calories of a food. This research supports the use of regression models for calorie prediction tasks (Antwl, J.B, Tuffour, Mensah, 2022).

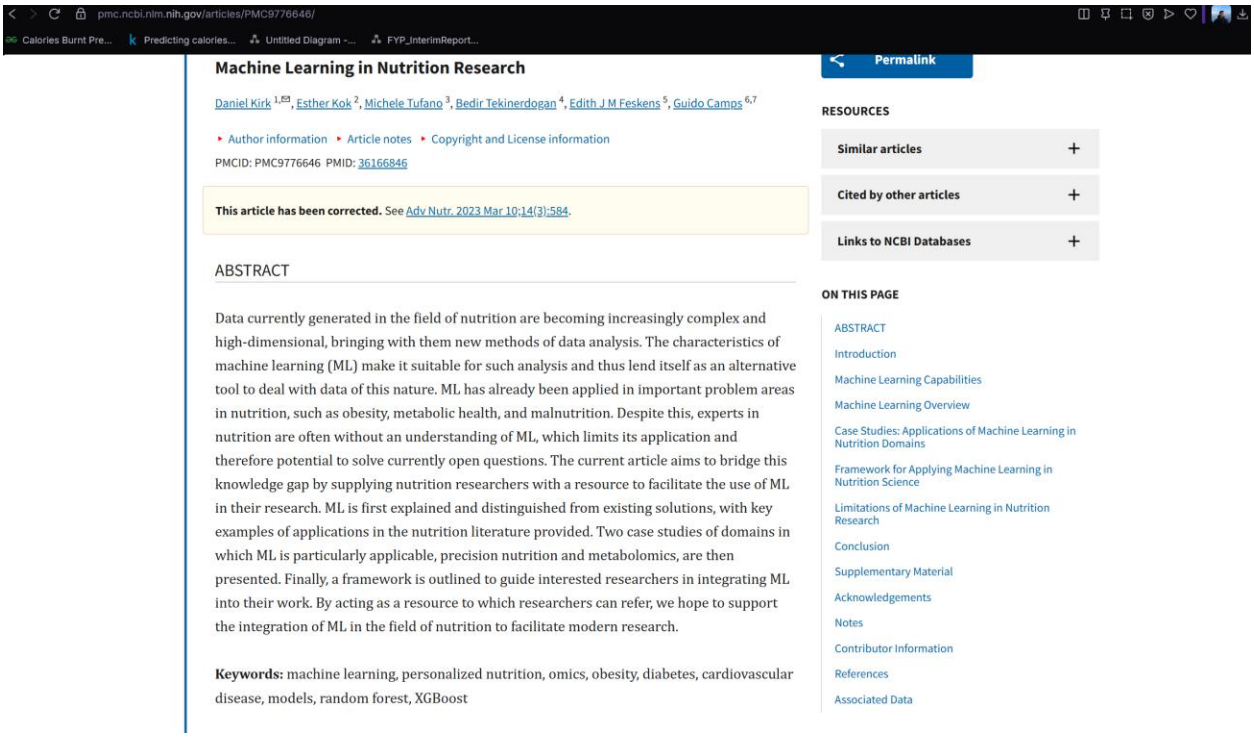


Figure 1: Article 1

2) AI Applications to Measure Food and Nutrient Intakes

This research analyses multiple artificial intelligence approaches used for estimating food and nutrient intake by reviewing supervised learning techniques, including regression-based models, that are applied to predict calories in a food. The authors highlight that machine learning models improve accuracy compares to manual traditional estimation methods (Zheng J, Wang J, Shen J, An R , 2023).

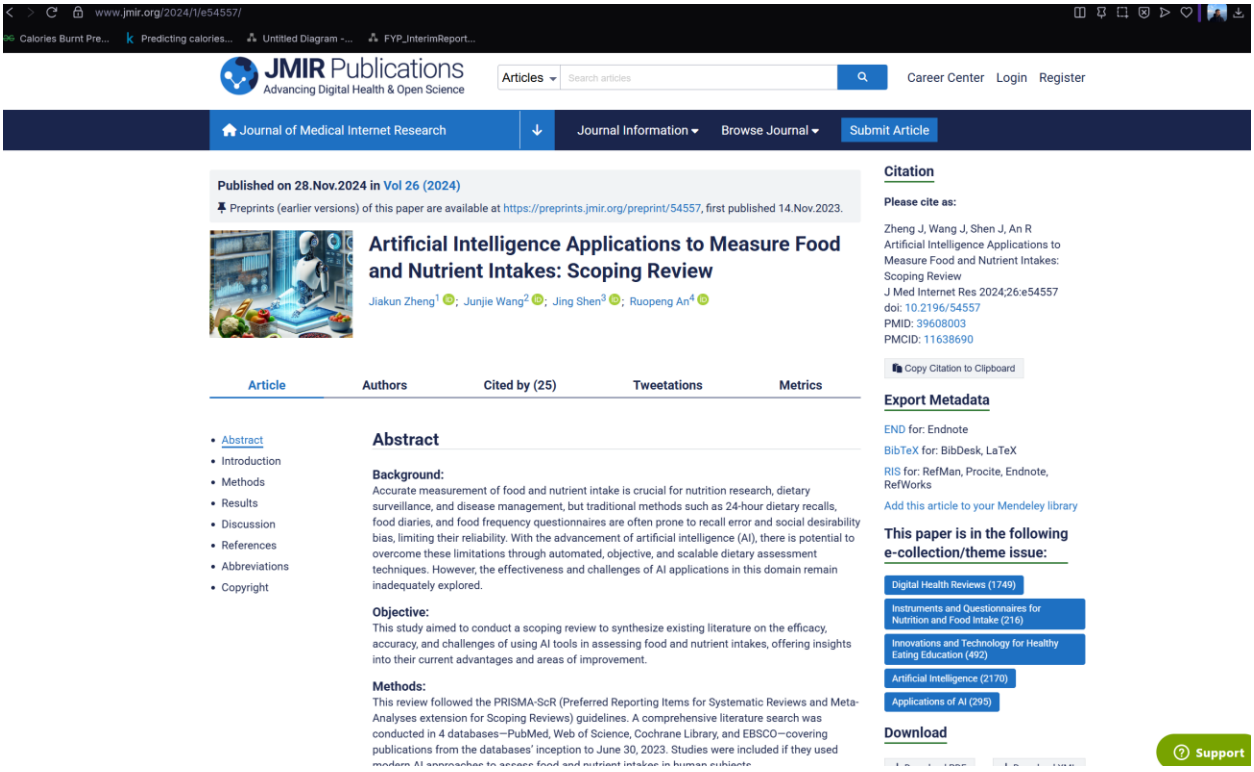


Figure 2: Article 2

3) Predicting Nutrient Density in Foods Using Machine Learning Models

This research focuses on predicting the nutrition density in food items using various machine learning regression models and compares algorithms such as Linear Regression, Decision Tree Regression, and Random Forest Regression to predict nutritional datasets. This study also shows performance metrics such as Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and R2 score are used to gain model accuracy. This study shows that Random Forest outperform simpler models due to their ability to capture non-linear relationships in nutritional data which directly aligns with the models used in this project (Changhe Yang, 2024).

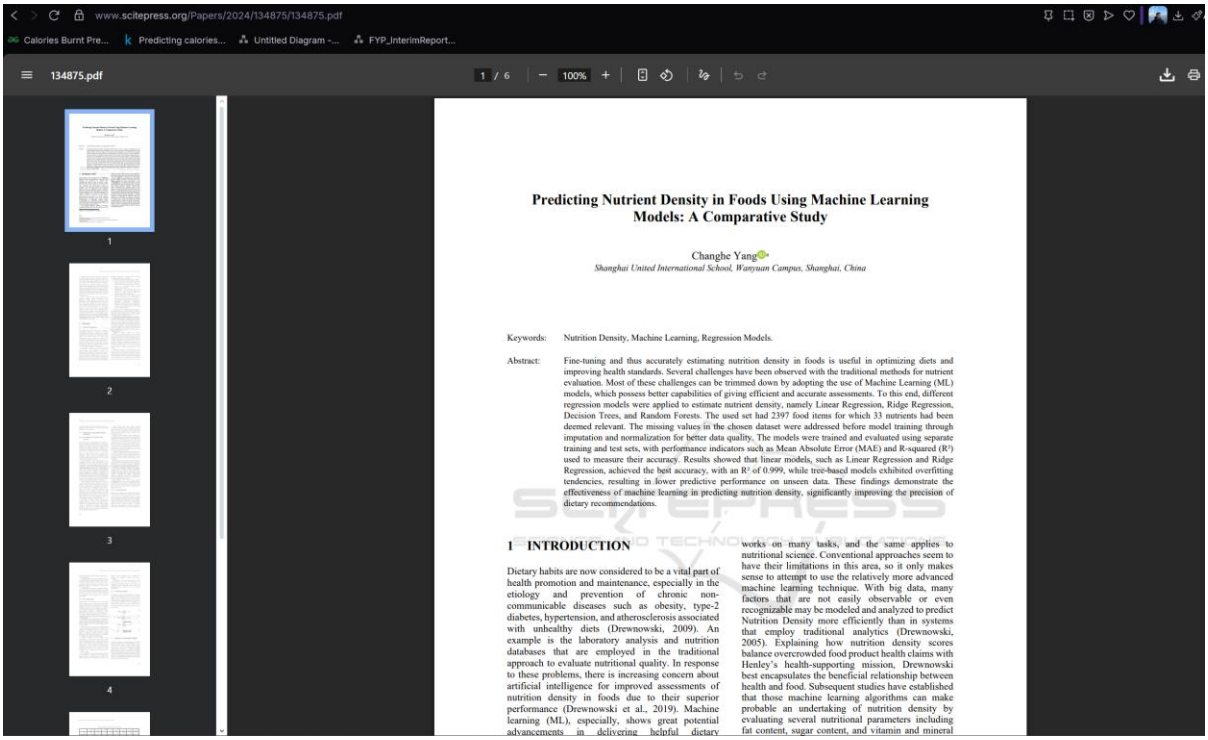


Figure 3: Article 3

3. Solution

3.1 Explanation of the Proposed Solution

The proposed solution for this project uses machine learning regression techniques to predict and estimate calorie content of food items based on their nutritional values. After reviewing the dataset obtained from Hugging Face, it was observed that detailed nutritional information for various food items such as carbohydrates, protein, fats, fiber and other nutrients including energy (kcal).

During initial data exploration, only the relevant attributes were selected for further analysis to ensure data quality and consistency. The dataset was then divided into training and testing sets to evaluate model performance on unseen data.

The proposed solution for this project involves developing a machine learning based system that predicts nutritional values using the selected food dataset. The system uses Linear Regression, Decision Tree, and Random Forest models to compare accuracy and performance. Linear Regression was initially implemented as a baseline model due to its simplicity as it is easier to interpret. Decision Tree Regressor was implemented to capture non-linear relationship between nutritional features and calorie values. Random forest was later introduced to improve prediction accuracy and reduce overfitting.

The performance of each of the mentioned model is evaluated using standard regression metrics, and the results are compared to determine the most effective approach to estimate and calories of a food.

3.2 Pseudocode of the solution

Pseudocode refers to the step-by-step description of an algorithm without using any programming language using simple English language for human understanding which helps developers to plan the system logic and structure before writing the actual coding part.

START

IMPORT required libraries

LOAD Food nutrition dataset

DISPLAY dataset structure and summary statistics

SELECT INPUT features (protein, carbohydrates, fats, etc.)

SELECT target variable (Energy kcal)

PREPROCESS data:

    HANDLE missing values

    APPLY feature scaling using StandardScaler

        For each feature:

            Compute mean and standard deviation

SPLIT dataset **INTO** training **AND** testing sets

FOR EACH algorithm **IN** [Linear Regression, Decision Tree, Random Forest]:

INITIALIZE model

TRAIN model **ON** training data

PREDICT calories **ON** test data

COMPUTE evaluation metrics:

Mean Absolute Error (MAE)

Root Mean Squared Error (RMSE)

R2 Score

STORE model performance results

COMPARE all models based on evaluation metrics

IDENTIFY best-performing model

VISUALIZE results using bar charts and heatmaps

END

3.2.1 Pseudocode for Linear Regression

START

IMPORT required libraries

LOAD nutrition dataset

SELECT input features (Protein, Carbohydrates, Fat, Fibre, Sugar, Cholesterol, Calcium)

SELECT target variables (Energy kcal)

PREPROCESS dataset:

    HANDLE missing values
    APPLY feature scaling using StandardScaler

SPLIT dataset into training and testing sets

INTIALIZE Linear Regression model

TRAIN model using training data

PREDICT calorie values for test data

EVALUATE model performance:

    COMPUTE MAE = average of [actual - predicted]

    COMPUTE RMSE = square root of average squared errors

    COMPUTE R2 = proportion of variance explained by model

STORE evaluation results

END

3.2.2 Pseudocode for Decision Tree Regressor

START

IMPORT required libraries

LOAD food nutrition dataset

SELECT input features (Protein, Carbohydrates, Fat, Fibre, Sugar, Cholesterol, Calcium)

SELECT target variables (Energy kcal)

PREPROCESS dataset:

    HANDLE missing values

SPLIT dataset into training and testing sets

INTIALIZE Decision Tree Regressor

TRAIN model using training data

PREDICT calorie values for test dataset

EVALUATE model performance:

    COMPUTE MAE

    COMPUTE RMSE

    COMPUTE R2 Score

STORE evaluation results

END

3.2.3 Pseudocode for Random Forest Regressor

START

IMPORT required libraries

LOAD nutrition dataset

SELECT input features (Protein, Carbohydrates, Fat, Fibre, Sugar, Cholesterol, Calcium)

SELECT target variables (Energy kcal)

PREPROCESS dataset:

    HANDLE missing values
    APPLY feature scaling where required

SPLIT dataset into training and testing sets

INTIALIZE Random Forest Regressor with multiple decision trees

TRAIN model using training data

PREDICT calorie values:

    COLLECT predictions from all trees

    COMPUTE final prediction as the average of all tree predictions

EVALUATE model performance:

    COMPUTE MAE

    COMPUTE RMSE

    COMPUTE R2 Score

STORE evaluation results

END

3.3 Diagrammatical Representation

3.3.1 Combined Flowchart

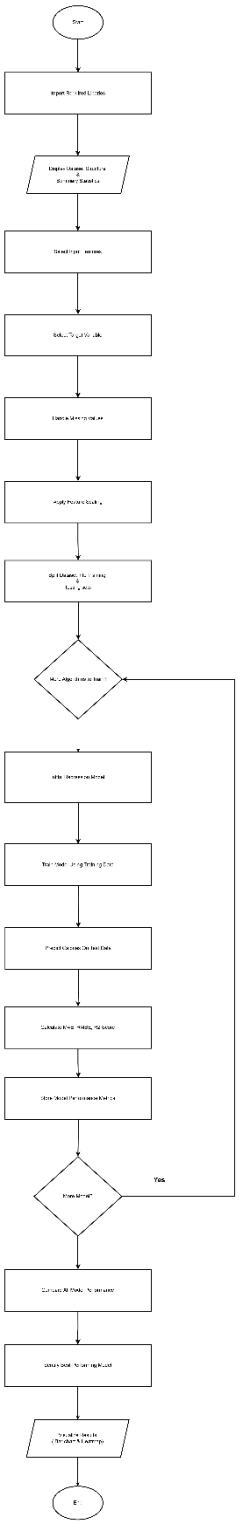


Figure 4: Combined Flowchart

3.3.2 Linear Regression Flowchart

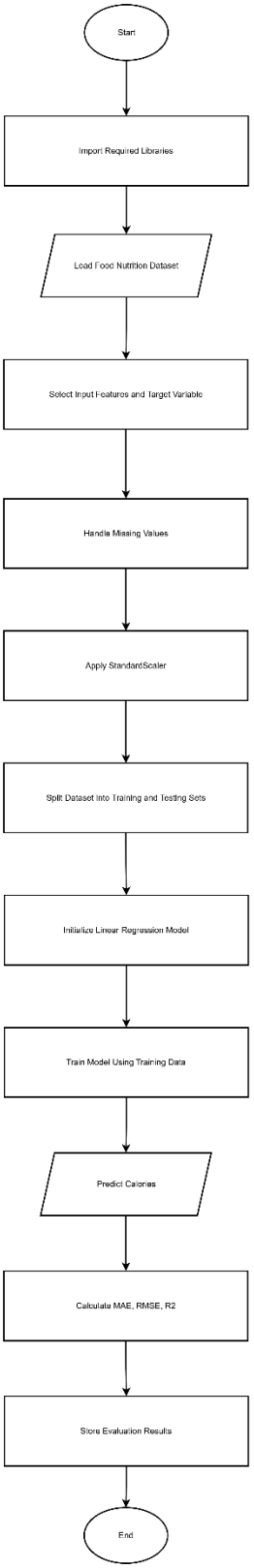


Figure 5: Linear Regression Flowchart

3.3.3 Decision Tree Regressor Flowchart

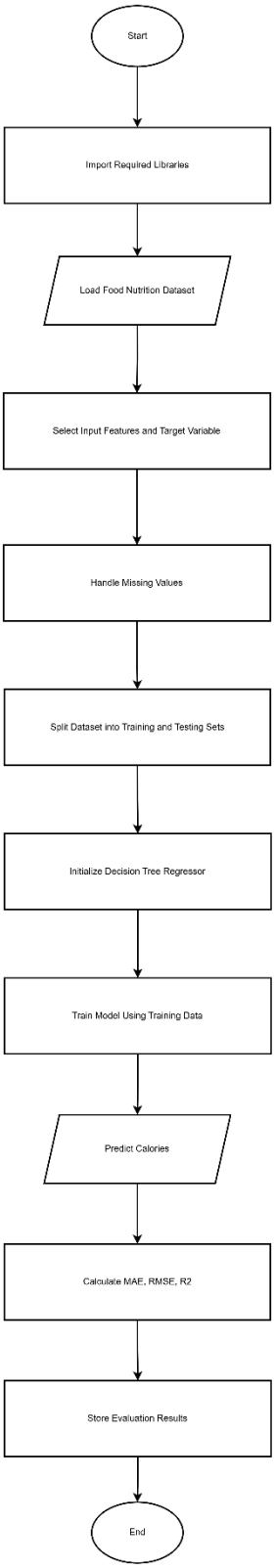


Figure 6: Decision Tree Regressor Flowchart

3.3.4 Random Forest Regressor Flowchart

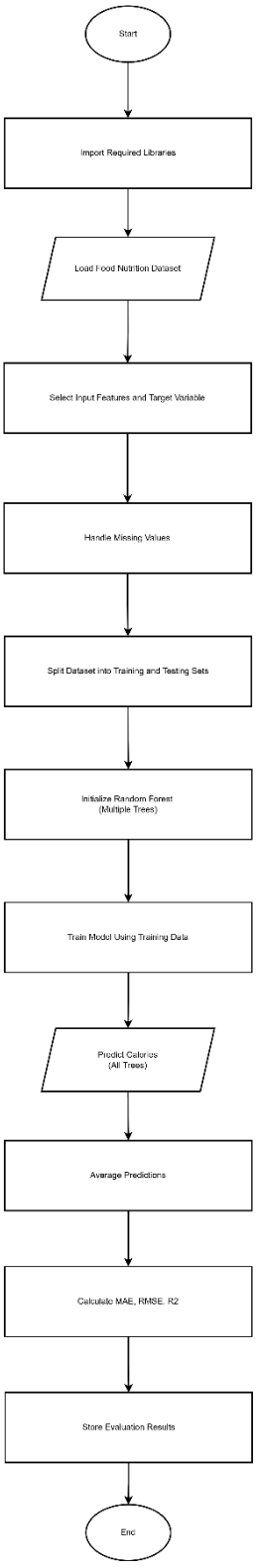


Figure 7: Random Forest Regressor Flowchart

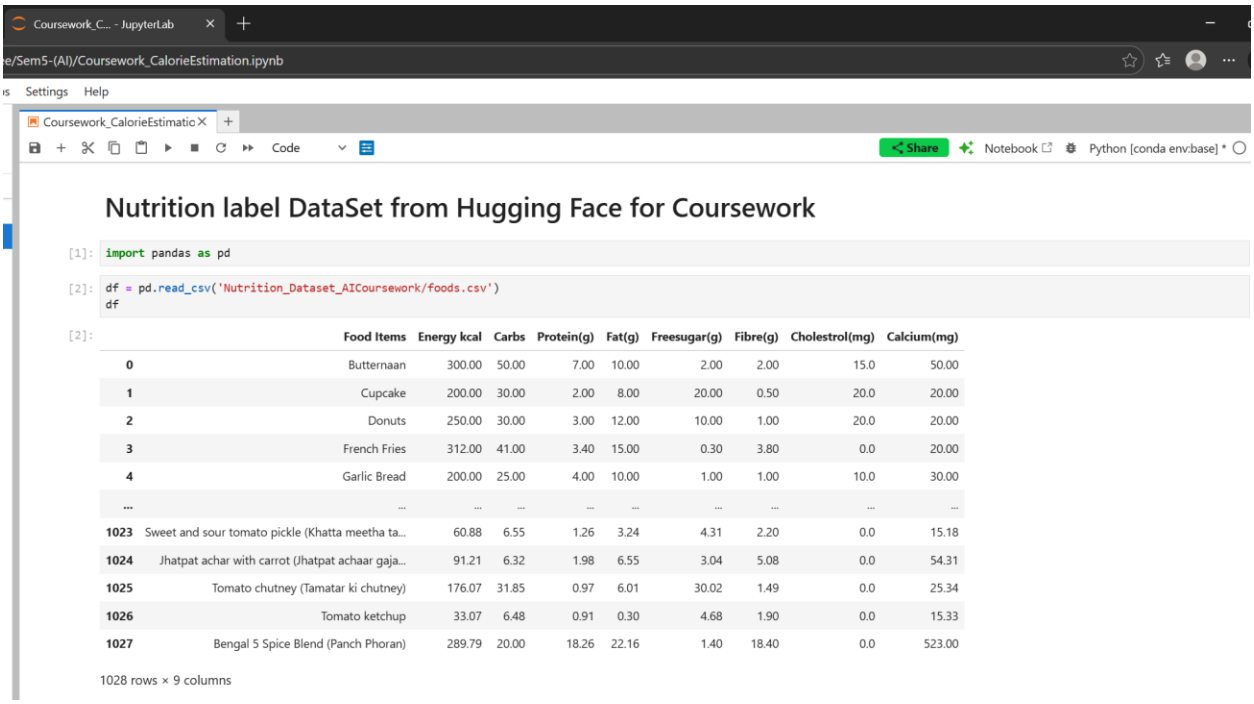
3.4 Explanation of Development Process

The development process for this project was done using Python programming language due to its extensive support for data analysis and machine learning and the implementation of the project was carried out in Jupyter Notebook, which allows interactive data exploration and visualization.

The development process began with data preparation, followed by model implementation and evaluation and the following key libraries were used during the development process:

1. Pandas: Data manipulation and pre-processing
2. NumPy: Numerical Computations
3. Scikit-learn: Implementing regression models and evaluation metrics
4. Matplotlib / Seaborn: Data visualization

3.5 Achieved Results



	Food Items	Energy kcal	Carbs	Protein(g)	Fat(g)	Freesugar(g)	Fibre(g)	Cholestrol(mg)	Calcium(mg)
0	Butternaan	300.00	50.00	7.00	10.00	2.00	2.00	15.0	50.00
1	Cupcake	200.00	30.00	2.00	8.00	20.00	0.50	20.0	20.00
2	Donuts	250.00	30.00	3.00	12.00	10.00	1.00	20.0	20.00
3	French Fries	312.00	41.00	3.40	15.00	0.30	3.80	0.0	20.00
4	Garlic Bread	200.00	25.00	4.00	10.00	1.00	1.00	10.0	30.00
...	...	...	...	...	...	...	...	...	...
1023	Sweet and sour tomato pickle (Khatta meetha ta...	60.88	6.55	1.26	3.24	4.31	2.20	0.0	15.18
1024	Jhatpat achar with carrot (Jhatpat achaar gaja...	91.21	6.32	1.98	6.55	3.04	5.08	0.0	54.31
1025	Tomato chutney (Tamatar ki chutney)	176.07	31.85	0.97	6.01	30.02	1.49	0.0	25.34
1026	Tomato ketchup	33.07	6.48	0.91	0.30	4.68	1.90	0.0	15.33
1027	Bengal 5 Spice Blend (Panch Phoran)	289.79	20.00	18.26	22.16	1.40	18.40	0.0	523.00

Figure 8: Loading Dataset in Jupyter notebook

Importing the Pandas library for data manipulation and analysis in Python.

pd.read_csv('Nutrition_Dataset_AICoursework/foods.csv') to load the raw nutrition dataset

Output:

Dataset has been successfully loaded, revealing a total of 1028 rows and 9 columns

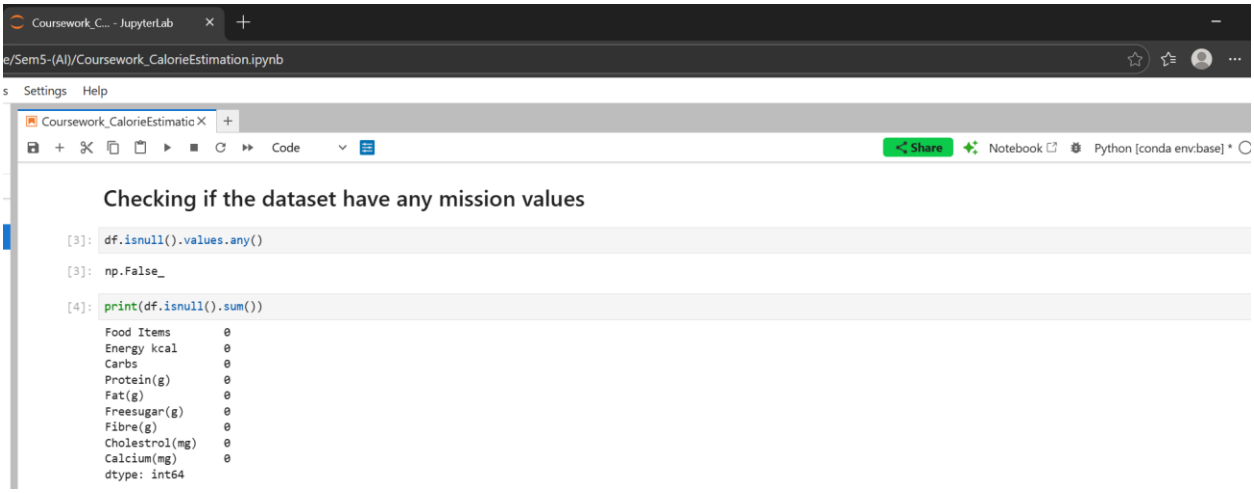


Figure 9: Checking for Missing NaN values

df.isnull().values.any() to check any missing values(NaN) in the dataset

print(df.isnull().sum()) to display total number of null entries in each columns

Output:

Dataset is complete with no missing values in any of the columns

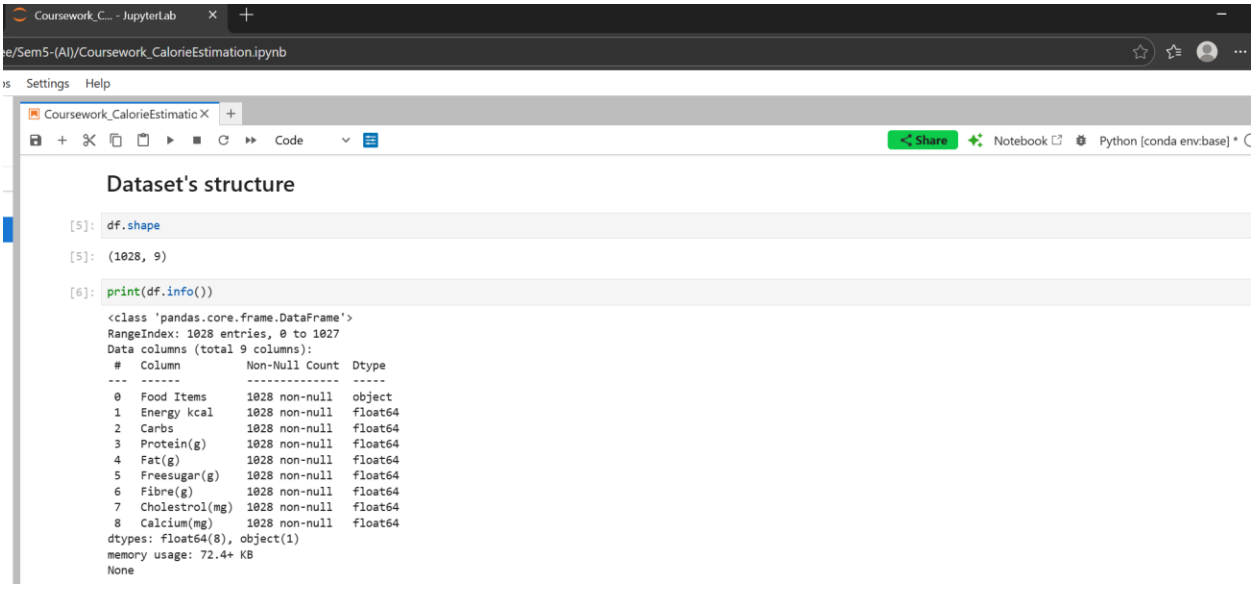


Figure 10: Checking Dataset Shape and Datatypes

df.shape to check the rows and columns of the dataset

df.info() to show summary of the dataframe, which includes number of null-null entries and the datatype of each columns

output:

Displays that the dataset consists of 1028 rows and 9 columns and reveals that 8 of the columns are numerical(float64) and 1 column is an object(string)

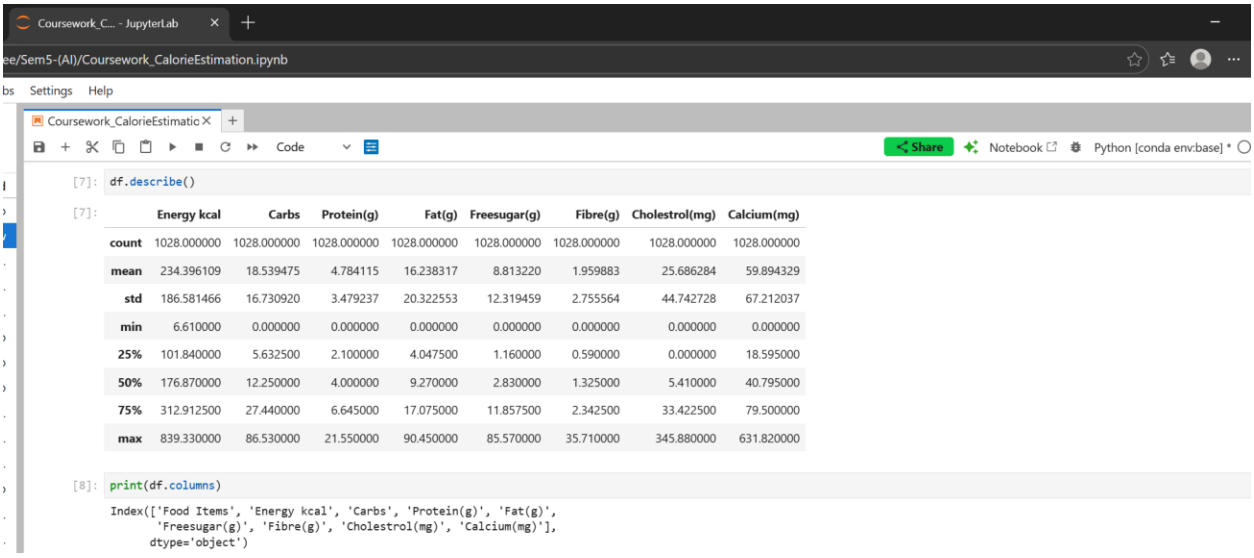


Figure 11: Statistical Summary of Numerical Columns

df.describe() generates statistics that shows central tendency, dispersion, and shape of the dataset's distribution

df.columns lists all the columns of the dataset

Output:

Mean, Standard deviation, minimum, maximum, and quartile values displayed for all nutritional attributes.

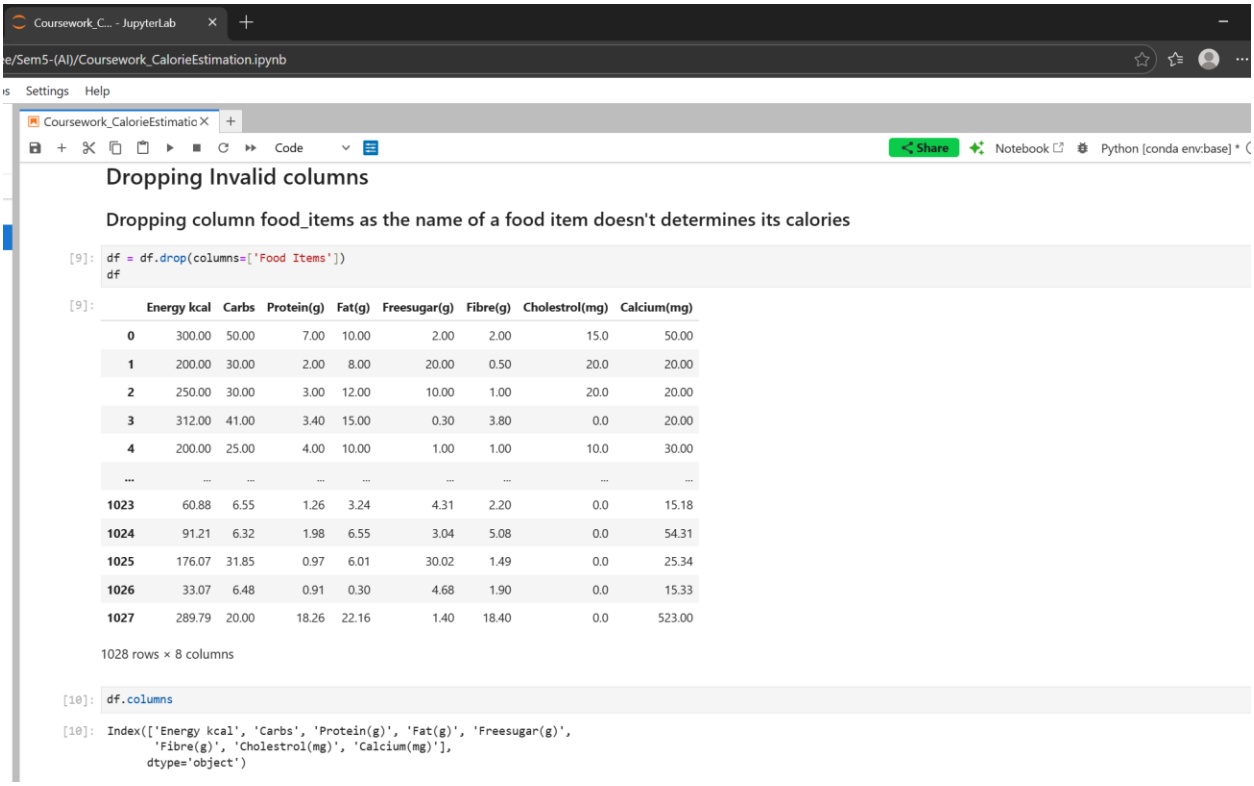


Figure 12: Dropping Invalid Columns

df.drop() removes the selected column from the dataset

Output:

Invalid column (food names) was dropped as it is not needed to estimate the calorie content of the food item.

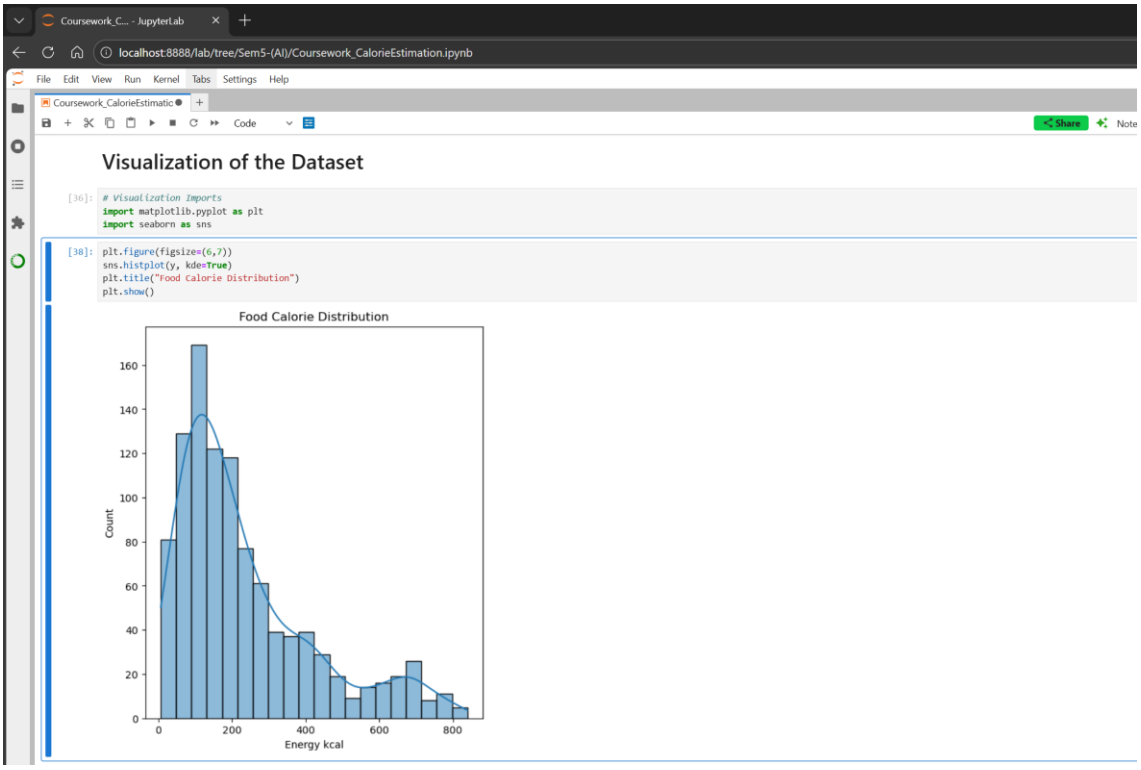


Figure 13: Calorie Distribution Chart

For Visual representation of data using **Seaborn** and **Matplotlib libraries**

sns.histplot() to visualize target variable and how calorie values are distributed across dataset

Output:

Displays distribution of right-skewed, therefore most of food items in the dataset contain lower calorie counts(0-300kcals), with fewer reaching the high end of the scale(>600kcals).

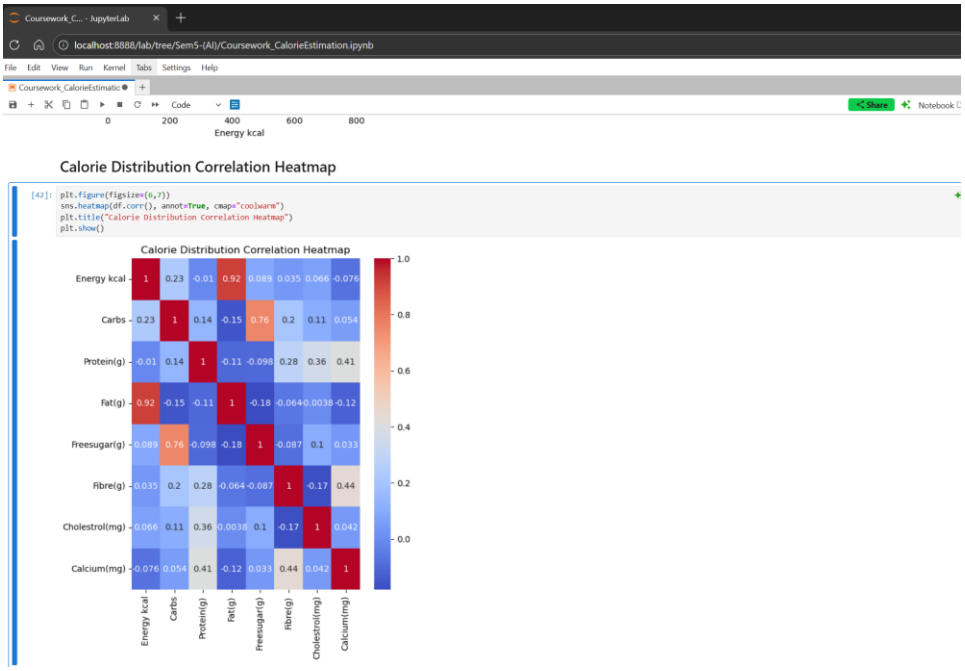


Figure 14: Calorie Distribution Heatmap

df.corr() to calculate the correlation matrix

sns.heatmap to visualize the correlation matrix

Output:

The heatmap shows a very strong positive correlation (0.92) between Fat(g) and Energy kcals, meaning the majority of the calories in food comes from fat contain.

It also shows that moderate correlation with Carbs (0.23), providing insight into which features the model should prioritize.

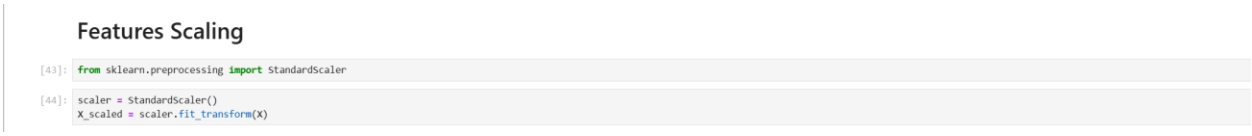


Figure 15: Feature Scaling for Linear Regression

StandardScaler library from Scikit-learn used to standardised different measuring scales to transform the data to mean of 0 and a standard deviation of 1.

Output:

Successfully normalized into x_scaled to scale the features with larger raw values.

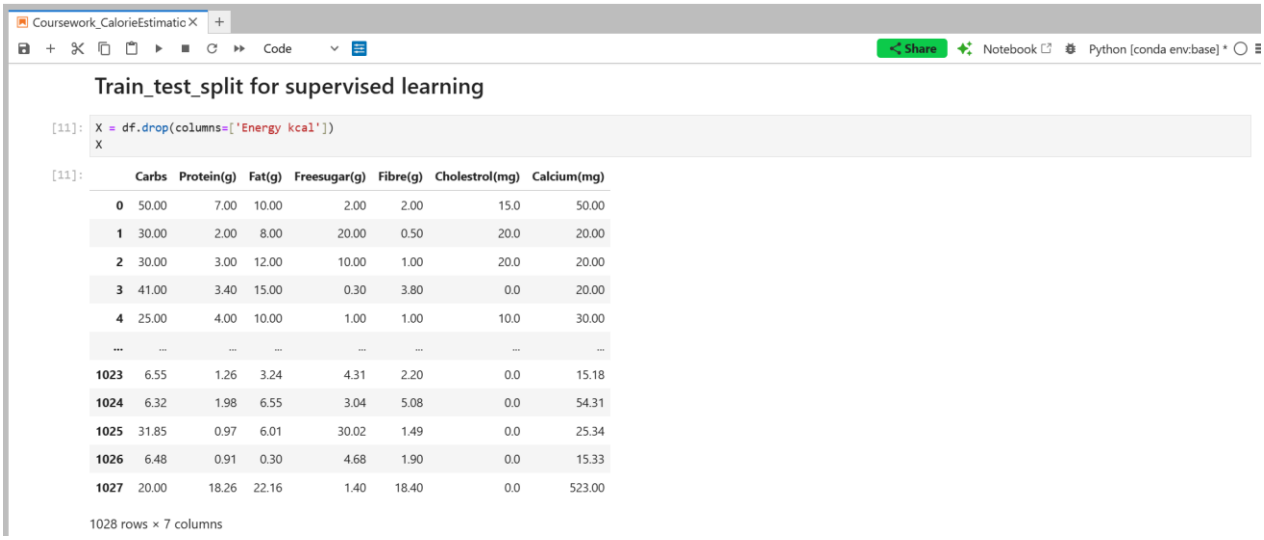


Figure 16: Input Feature(X) for train_test_split

Output:

Separated the independent variables (Features) from the dependent variable and creating a new DataFrame X to contain only the nutritional components.

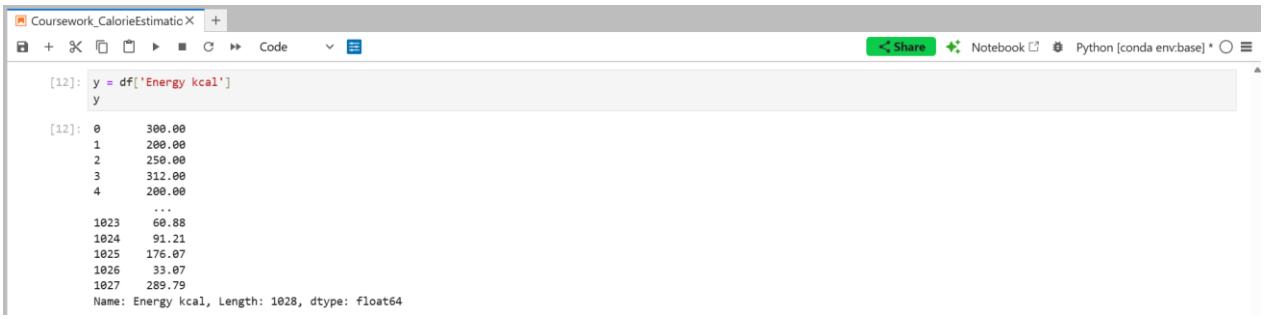
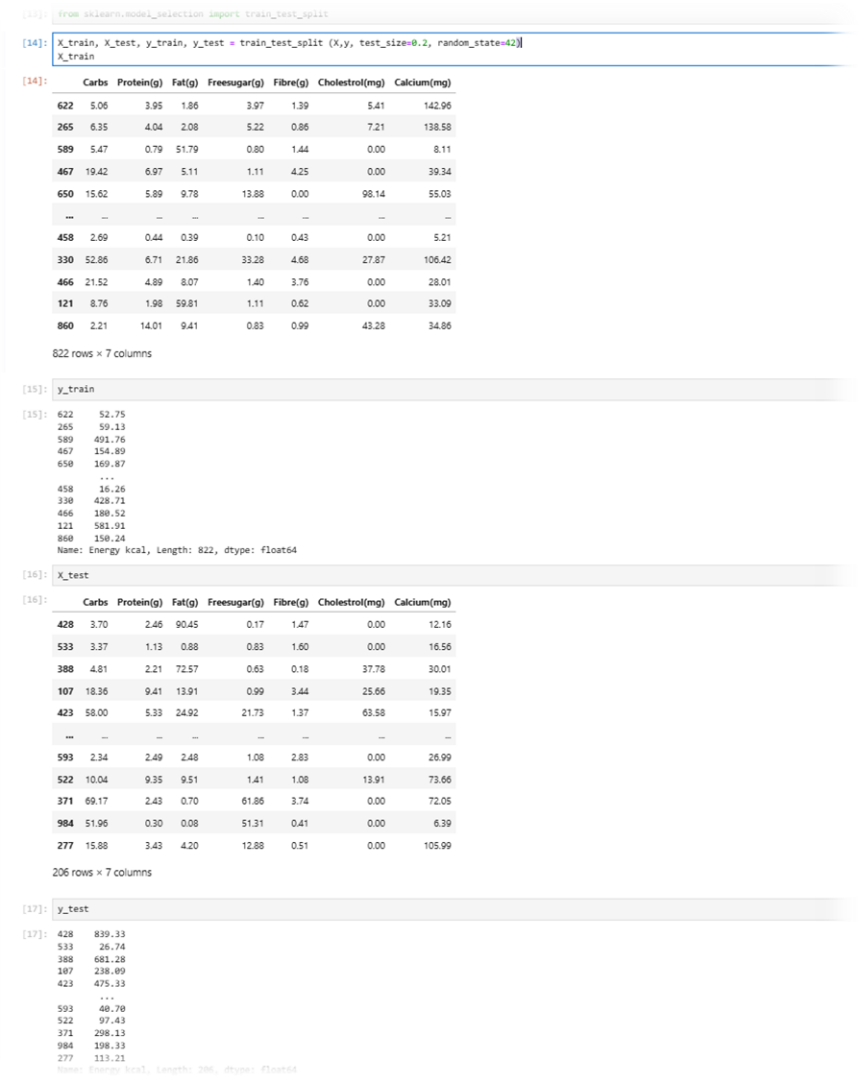


Figure 17: Target Variable(y) for train_test_split

Output:

Displays the target variable, which is the value to predict.



```
[13]: from sklearn.model_selection import train_test_split

[14]: X_train, X_test, y_train, y_test = train_test_split (X,y, test_size=0.2, random_state=42)
      X_train
```

[14]:

	Carbs	Protein(g)	Fat(g)	Freesugar(g)	Fibre(g)	Cholestrol(mg)	Calcium(mg)
622	5.06	3.95	1.86	3.97	1.39	5.41	142.96
265	6.35	4.04	2.08	5.22	0.86	7.21	138.58
589	5.47	0.79	51.79	0.80	1.44	0.00	8.11
467	19.42	6.97	5.11	1.11	4.25	0.00	39.34
650	15.62	5.89	9.78	13.88	0.00	98.14	55.03
...	...	...	...	...	...	...	...
458	2.69	0.44	0.39	0.10	0.43	0.00	5.21
330	52.86	6.71	21.86	33.28	4.68	27.87	106.42
466	21.52	4.89	8.07	1.40	3.76	0.00	28.01
121	8.76	1.98	59.81	1.11	0.62	0.00	33.09
860	2.21	14.01	9.41	0.83	0.99	43.28	34.86

822 rows × 7 columns

```
[15]: y_train
```

```
[15]: 622     52.75
      265     59.13
      589    491.76
      467    154.89
      650    169.87
              ...
      458     16.26
      330    428.71
      466    180.52
      121    581.91
      860    150.24
      Name: Energy kcal, Length: 822, dtype: float64
```

```
[16]: X_test
```

[16]:

	Carbs	Protein(g)	Fat(g)	Freesugar(g)	Fibre(g)	Cholestrol(mg)	Calcium(mg)
428	3.70	2.46	90.45	0.17	1.47	0.00	12.16
533	3.37	1.13	0.88	0.83	1.60	0.00	16.56
388	4.81	2.21	72.57	0.63	0.18	37.78	30.01
107	18.36	9.41	13.91	0.99	3.44	25.66	19.35
423	58.00	5.33	24.92	21.73	1.37	63.58	15.97
...	...	...	...	...	...	...	...
593	2.34	2.49	2.48	1.08	2.83	0.00	26.99
522	10.04	9.35	9.51	1.41	1.08	13.91	73.66
371	69.17	2.43	0.70	61.86	3.74	0.00	72.05
984	51.96	0.30	0.08	51.31	0.41	0.00	6.39
277	15.88	3.43	4.20	12.88	0.51	0.00	105.99

206 rows × 7 columns

```
[17]: y_test
```

```
[17]: 428    839.33
      533     26.74
      388    681.28
      107    238.09
      423    475.33
              ...
      593     40.70
      522     97.43
      371    298.13
      984    198.33
      277    113.21
      Name: Energy kcal, Length: 206, dtype: float64
```

Figure 18: Train_test_split

train_test_split used to divide the data into 2 separated sets

test_size=0.2 80% of data used for training and 20% data reserved to test performance on unseen data.

random_state=42 ensures that the random value generated always remains constant.

Output:

Data split into 822 training samples and 206 testing samples.

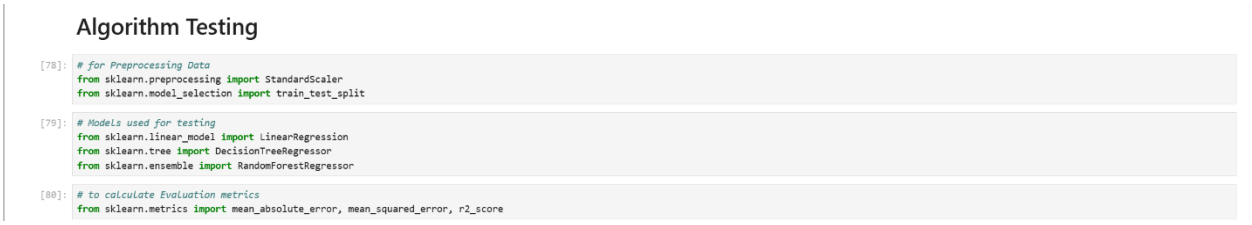


Figure 19: Imports for algorithm testing

Output:

Imports for all the libraries used

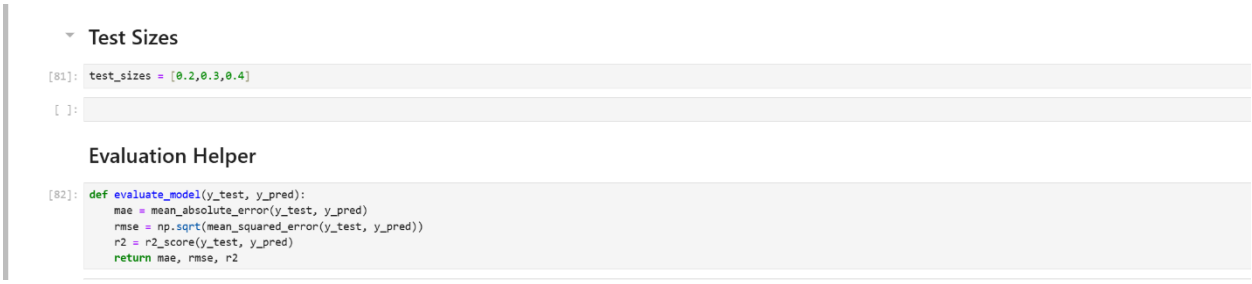


Figure 20: Test sizes and Evaluation

Output:

3 different Test sizes for the algorithms where:

1. 80% Train, 20% Test
2. 70% Train, 30% Test
3. 60% Train, 40% Test

Figure 21: Linear Regression

Output:

Provides the baseline for the project, uses **For** loop to iterate through different test sizes, spitted scaled features (X_scaled)

.fit() training the model

lr_results to store results in a dedicated list

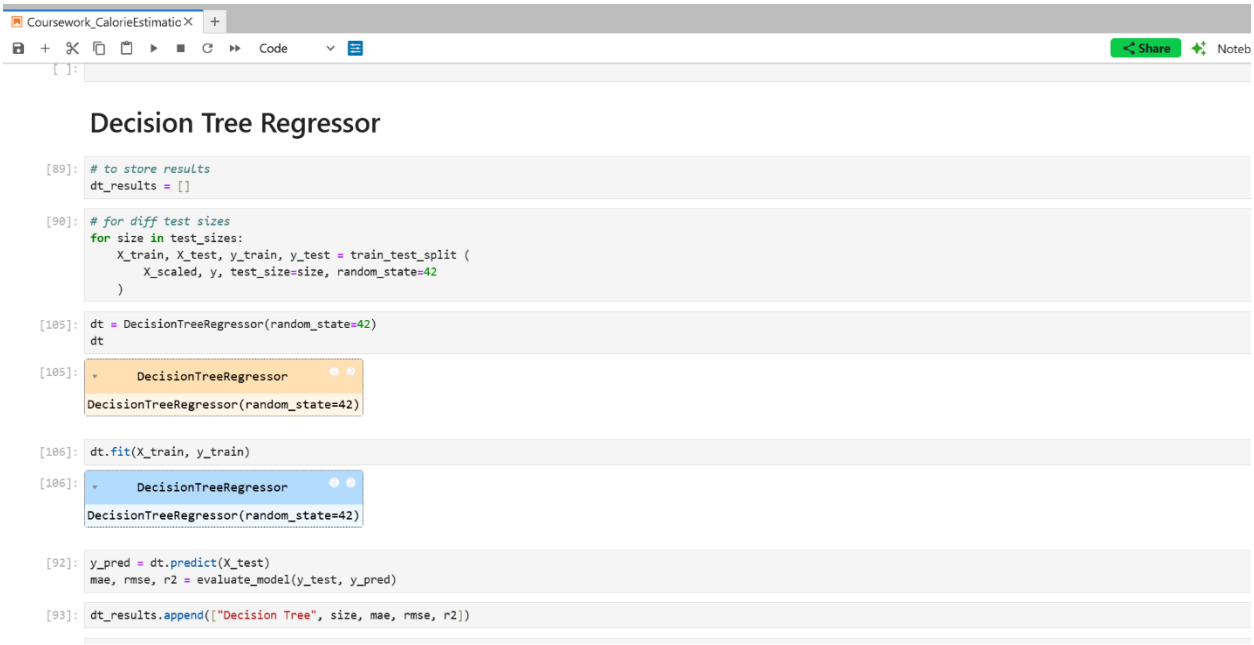


Figure 22: Decision Tree Regressor

Output:

Non-linear relationships shown

Displays complexity of a single tree compared to the linear baseline

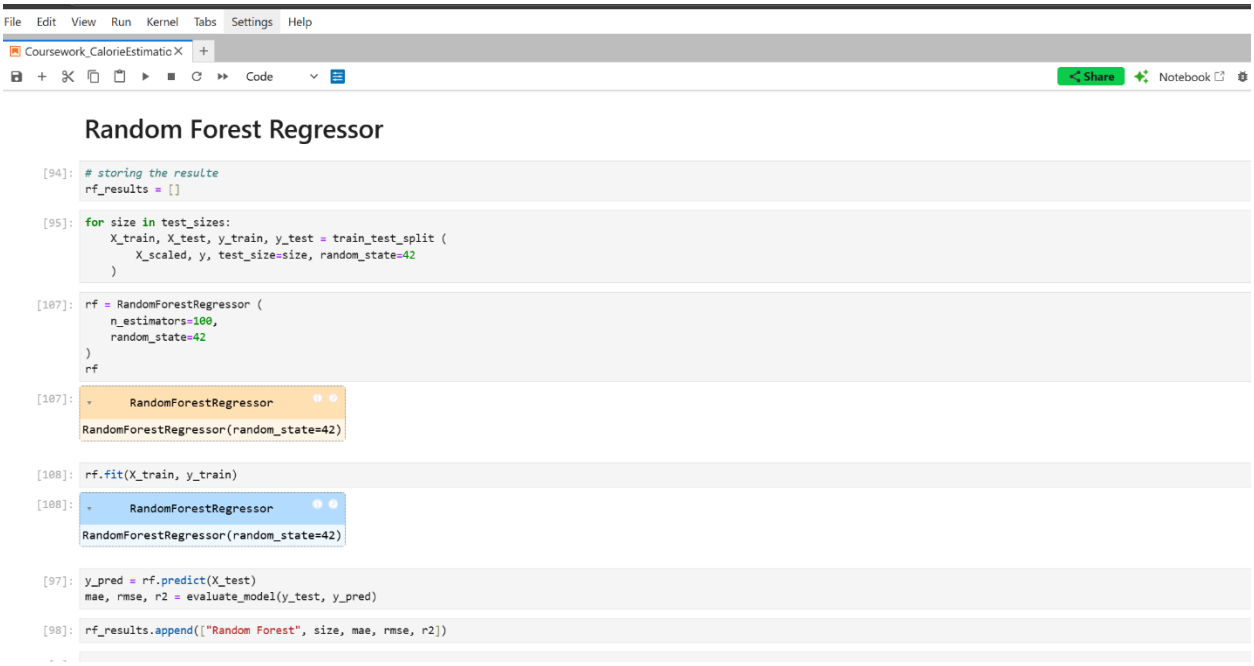


Figure 23: Random Forest Regressor

Output:

100 individual decision trees ensembled to improve accuracy and reduce the risk of overfitting.

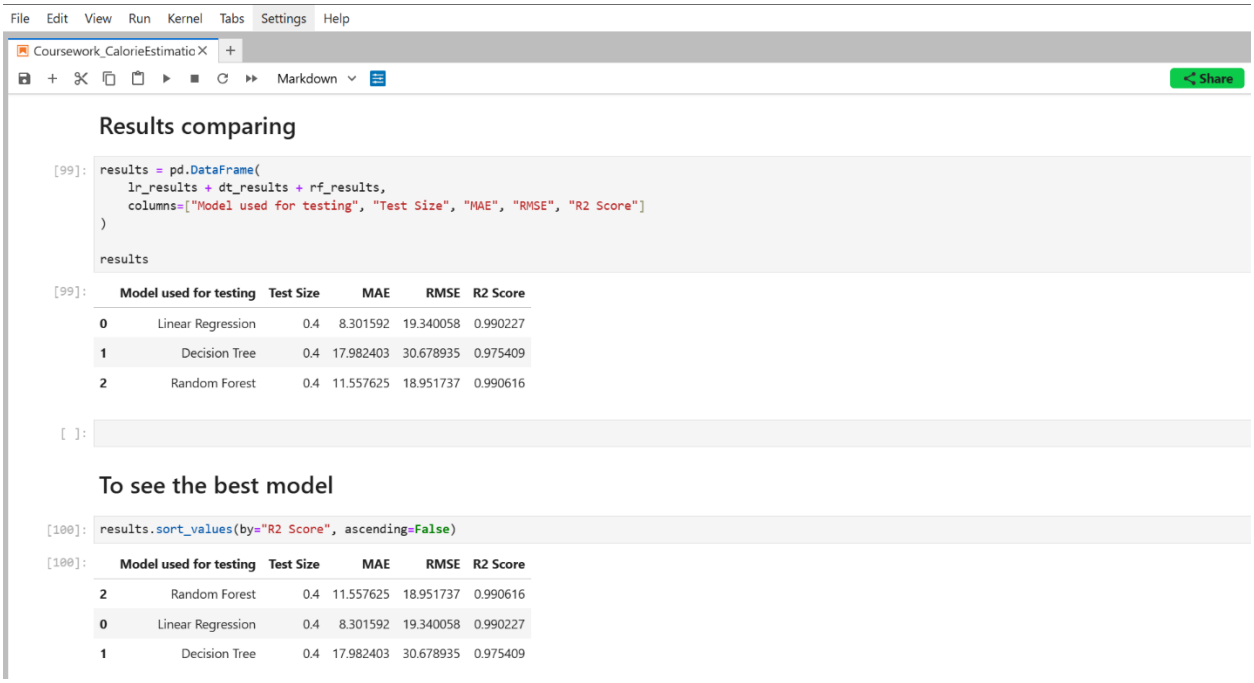


Figure 24: Result Comparing and Best Model Selection

Output:

Displays ranking of all the models based on all the test sizes

Random forest model shows the highest R2 score

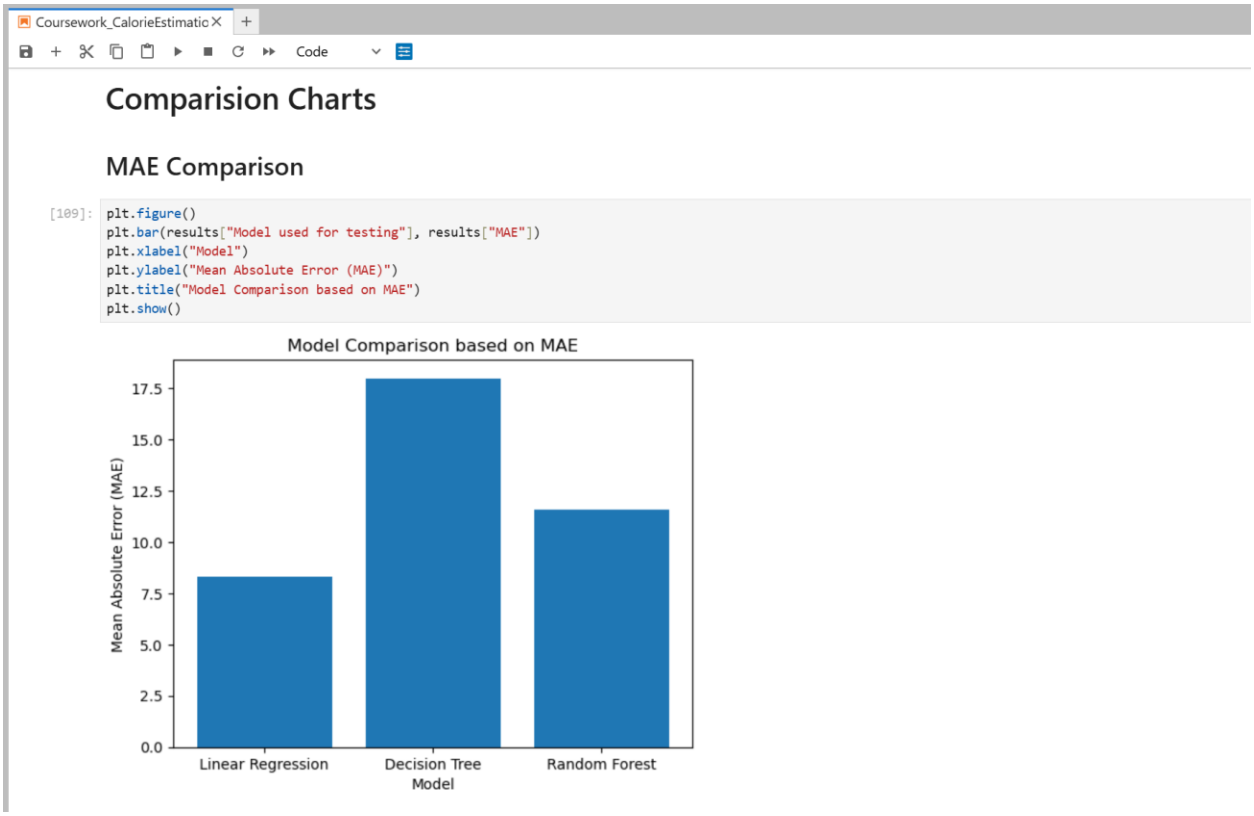


Figure 25: MAE Comparison

Output:

MAE value for all the models compared with the help of a bar chart.

RSME Comparison

```
[110]: plt.figure()
plt.bar(results["Model used for testing"], results["RMSE"])
plt.xlabel("Model")
plt.ylabel("Root Mean Squared Error (RMSE)")
plt.title("Model Comparison based on RMSE")
plt.show()
```

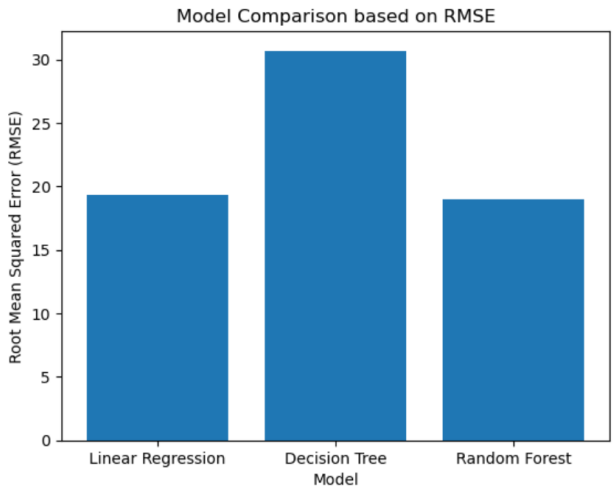


Figure 26: RSME Comparison

Output:

RSME value for all the model compared with the help of a bar chart.

R2 Comparison

```
[114]: plt.figure()
plt.bar(results["Model used for testing"], results["R2 Score"])
plt.xlabel("Model")
plt.ylabel("R² Score")
plt.title("Model Comparison based on R² Score")
plt.show()
```

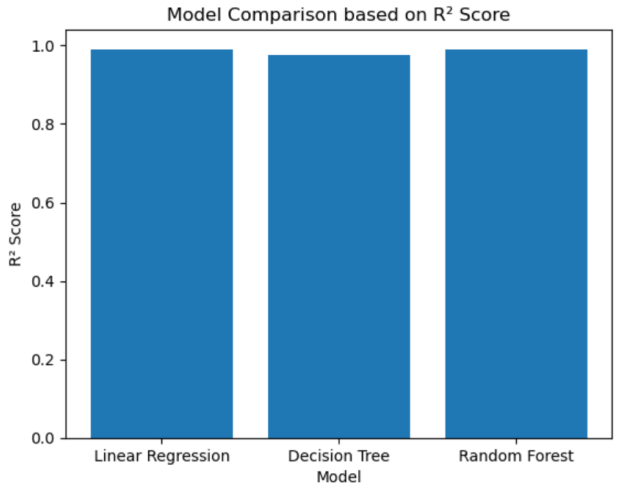


Figure 27: R2 Comparison

Output:

R2 score for all the models compared using a bar chart visualization.

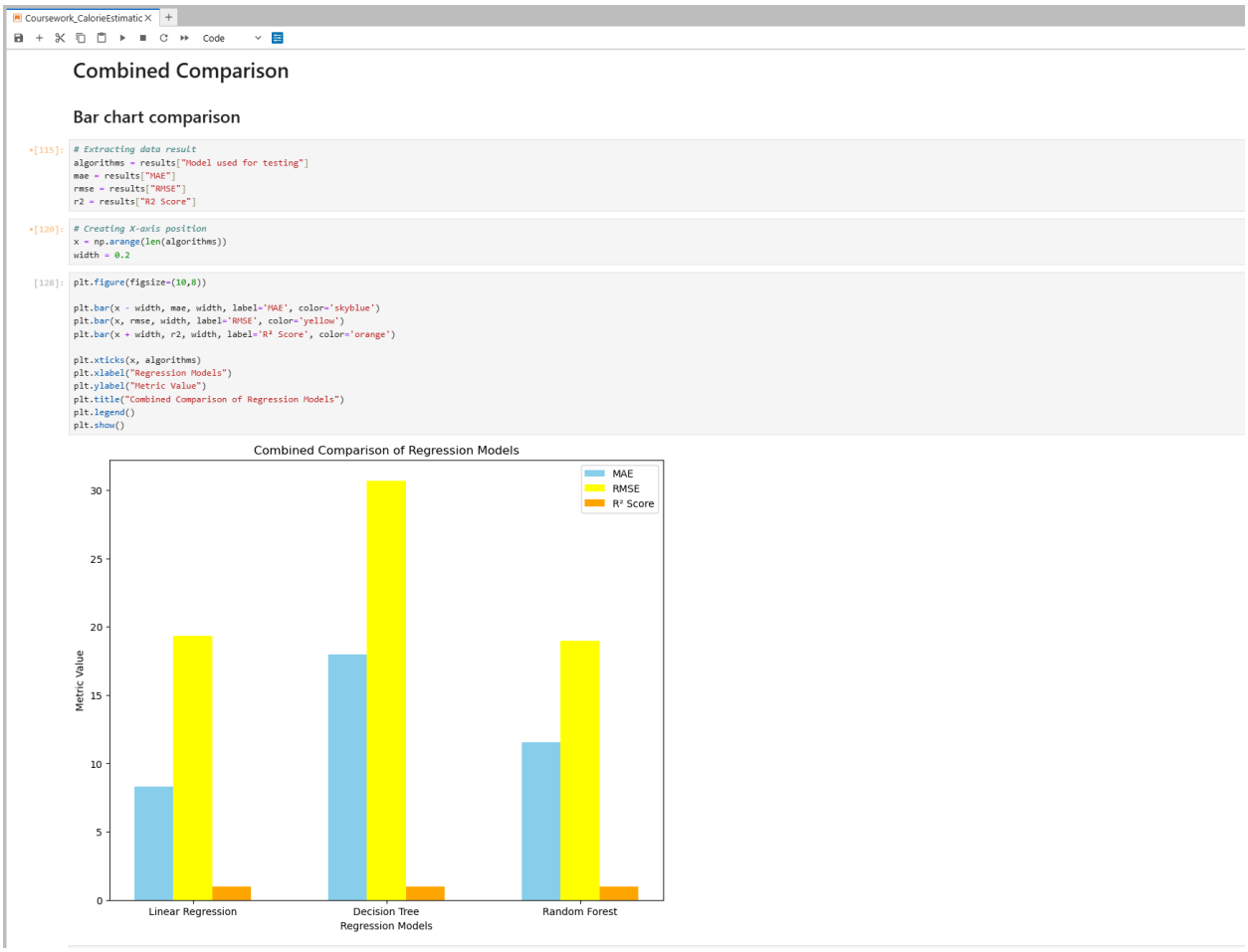


Figure 28: Combined Bar Chart Comparison of all Algorithms

Output:

Shows multi-dimensional comparison between the models which shows that Decision Tree model is the least accurate model for this dataset.

Coursework_CalorieEstimatic

Code

Heatmap Comparison for the models

```
[129]: # for model result data
heatmap_data = results.set_index("Model used for testing")
```

```
[137]: plt.figure(figsize=(10,8))
sns.heatmap(heatmap_data, annot=True, fmt=".2f", cmap="coolwarm",linewidths=0.5)
plt.title("Heatmap Comparison of Regression Models")
plt.xlabel("Evaluation Metrics")
plt.ylabel("Regression Models")
plt.show()
```

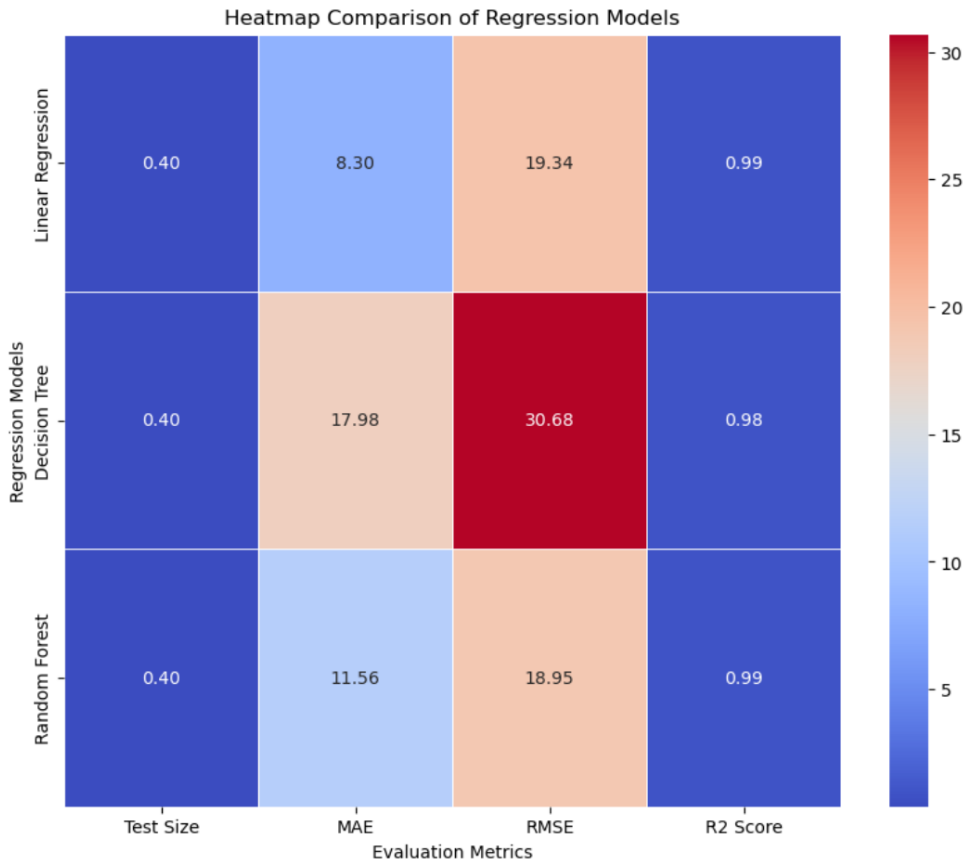


Figure 29: Heatmap Comparison of all Algorithms

Output:

Displays a dense summary of results, which shows that Decision Tree contains the highest RMSE, while Random Forest and Linear Regression shows high predictive reliability across all metrics.

4. Conclusion

In conclusion, this project focused on predicting the calorie content of food items in the dataset using nutritional attributes of the food items. Machine learning regression techniques including Linear Regression, Decision Tree Regressor, and Random Forest Regressor were implemented and evaluated to estimate calorie values.

The dataset was pre-processed by handling missing values. Applying feature scaling, and splitting the data into training and testing sets. Further each model was trained and evaluated using regression performance metrics such as Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), and R2 score. Overall, the comparative analysis showed that based models, particularly Random Forest Regressor, provided better prediction performance compared to simpler models due to their ability to capture non-linear relationships between nutritional features and calorie content.

This project provided valuable insight into how machine learning techniques can be effectively applied to nutritional data to estimate calorie content, which has real-world relevance in health monitoring, dietary planning, and food analysis systems. Future improvements could include incorporating larger datasets, additional nutritional attributes, hyperparameter tuning, and cross-validation techniques to further improve prediction accuracy of the system.

5. References

1. Antwl, J.B, Tuffour, Mensah, 2022. Machine Learning in Nutrition Research. *Nutrition Journal,* Issue https://pmc.ncbi.nlm.nih.gov/articles/PMC9776646/.

2. Changhe Yang, 2024. Predicting Nutrient Density in Foods Using Machine Learning Models. *DAMI 2024,* p. 6.

3. Zheng J, Wang J, Shen J, An R , 2023. Artificial Intelligence Applications to Measure Food and Nutrient Intakes. *Nutrition Journal,* Issue https://www.jmir.org/2024/1/e54557/.