Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol.12 Issue 12, DECEMBER 2023

Predicting Individual Energy Consumption Using Machine Learning Models

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ABSTRACT
In an era characterized by increased awareness of environmental concerns and the importance of energy conservation, the accurate prediction of individual energy consumption is a critical endeavour. This journal paper presents a comprehensive approach to forecast the energy usage of individuals by harnessing the power of machine learning algorithms. The study covers data collection, pre-processing, model selection, training, evaluation, deployment, and the interpretation of results. The primary aim is to empower individuals and utility companies with invaluable insights into predicting and optimizing energy usage, thereby reducing environmental impact and promoting energy efficiency.

Keywords: Machine Learning, Energy Consumption, Regression Analysis, Feature Engineering, Model Evaluation

1. INTRODUCTION

The challenges posed by our increasing reliance on energy resources, coupled with a growing global population, necessitate innovative approaches to energy conservation and efficient resource management [1]. At the heart of these endeavours lies the accurate prediction of individual energy consumption [2]. The ability to forecast how individuals use energy not only holds considerable economic implications for households but also plays a pivotal role in shaping broader environmental sustainability and energy management goals [3]. This journal paper delves into a comprehensive study on predicting individual energy consumption through the application of machine learning models [4]. The growing concerns over energy conservation, environmental sustainability, and the need for efficient energy management have prompted researchers and industry stakeholders to explore innovative ways to predict individual energy consumption [4]. Predicting individual energy consumption not only has financial implications for individuals but also contributes significantly to broader environmental and sustainability goals[5]. Accurate forecasts enable consumers to better understand and manage their energy usage, while utility companies can optimize resource allocation and reduce environmental impact [6]. This study aims to address these objectives by employing machine learning models to predict individual energy consumption shown in fig-1.

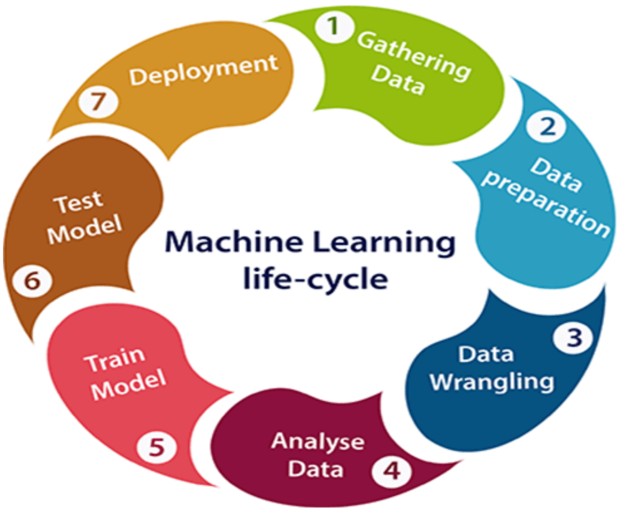

Fig.1 MACHINE LEARNING LIFE CYCLE

1.1 Background and Significance

In a world characterized by the accelerating depletion of finite energy resources, the urgent need to transition towards sustainable, energy-efficient practices is unmistakable. Sustainability is no longer an option but a mandate, driven by concerns over environmental degradation, the existential threat of climate change, and the rising cost of energy production. In this context, understanding how individuals consume energy is paramount. It enables the development of informed strategies for energy conservation, reduced environmental impact, and a more sustainable future.
Predicting individual energy consumption is a multifaceted challenge that offers a range of societal and economic benefits. For individuals, such forecasts can inform choices that lead to cost savings, promote energy efficiency, and reduce the financial burden of utility bills. For utility companies, accurate predictions can aid in resource allocation, grid management, and the provision of

International Journal of Engineering Research & Technology (IJERT)
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real-time feedback to consumers, fostering a culture of responsible energy consumption. Furthermore, at a macro level, these predictions contribute to the attainment of renewable energy integration and greenhouse gas emission reduction objectives.

1.2 Motivation for the Study
The motivation behind this study stems from the critical need to develop advanced tools and methodologies for energy prediction. As our society becomes increasingly interconnected and data-rich, the fusion of machine learning techniques with energy forecasting offers a profound opportunity. It allows us to unlock the latent potential of data-driven decision-making and energy conservation in ways never before imagined. The knowledge that this endeavour brings is invaluable, equipping individuals, utility providers, and policy makers with the insights required to make informed choices and drive sustainable practices.

2. DATA COLLECTION AND PRE-PROCESSING

The foundation of accurate energy consumption prediction, in a software-centric approach, relies on the quality and effective pre-processing of data obtained from digital sources. This section delves into the process of data collection, cleaning, feature engineering, and data partitioning, with a focus on software-driven methods as per below fig-2.

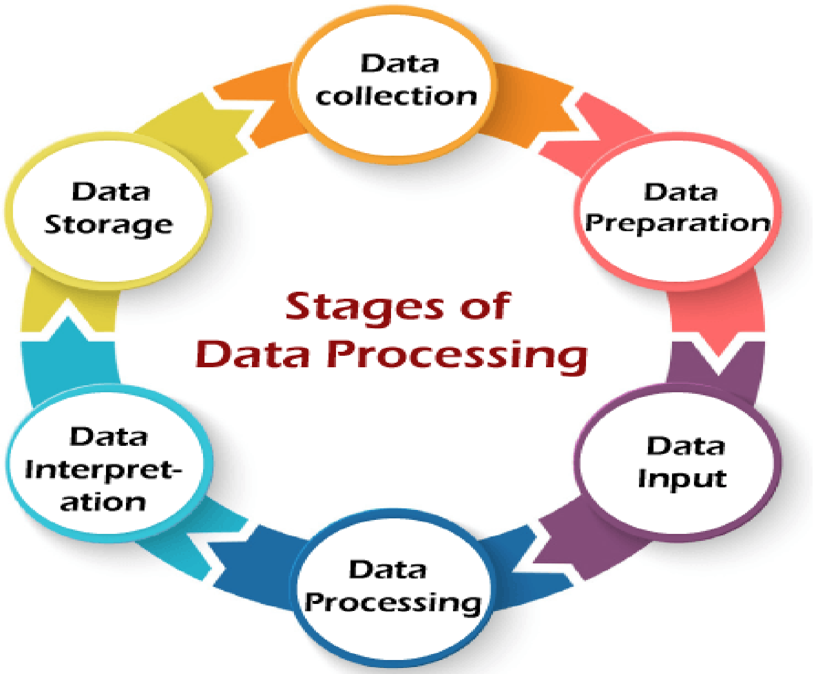

Fig.2 STAGES OF DATA PROCESSING

2.1 Data Sources
In this software-driven approach, we primarily rely on digital data sources, as follows:
Utility Data: Historical energy consumption records were obtained digitally from utility companies, providing a wealth of information about past energy usage. These records offer granularity and context for predictive modelling.
Online Surveys and User Inputs: Surveys and online platforms were used to collect individual characteristics and lifestyle information. Participants' responses provided essential data points for constructing the dataset, including demographic information, household size, and specific details about energy-consuming devices and habits.
Weather APIs: Real-time and historical weather data were sourced from online Application Programming Interfaces (APIs). Temperature, humidity, and weather conditions are critical factors influencing energy consumption, and this digital data source enables real-time updates.

2.2 Data Cleaning
The digital dataset was subjected to meticulous data cleaning, ensuring data reliability and consistency:
Handling Missing Data: Software-based imputation techniques, including mean imputation for continuous features and mode imputation for categorical variables, addressed missing values.
Outlier Detection: Advanced data analytics were used to detect outliers, which were subsequently evaluated and, if necessary, treated to minimize their impact on model performance.
Consistency Checks: Inconsistencies, such as conflicting records, were systematically resolved to ensure the integrity of the digital dataset as per below fig-3.

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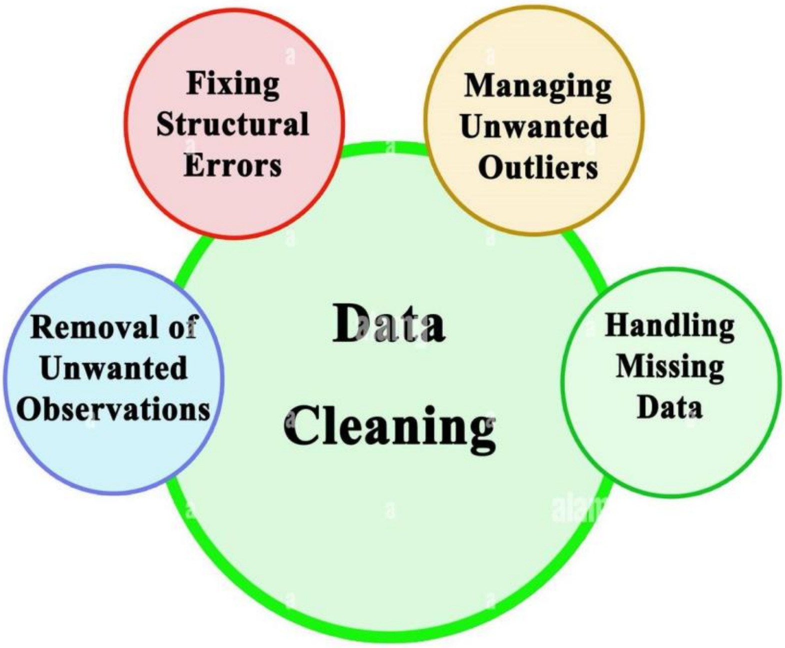

Fig.3 DATA CLEANING

2.3 Feature Engineering
Effective feature engineering is essential in a software-based approach, given the abundance of digital data. Features were created to capture the nuanced relationship between user characteristics, weather, and energy consumption. Some feature examples include:
Seasonal Indicators: Binary features representing seasons, such as summer, winter, and transitional periods, were engineered to reflect the influence of changing weather conditions on energy usage.
Normalized Temperature: A feature normalizing temperature fluctuations relative to individual heating or cooling preferences was devised, accommodating subjective temperature comfort levels.
Historical Consumption Trends: Time-series features, encompassing monthly and daily consumption averages, were constructed to capture temporal consumption patterns as per below fig-4.

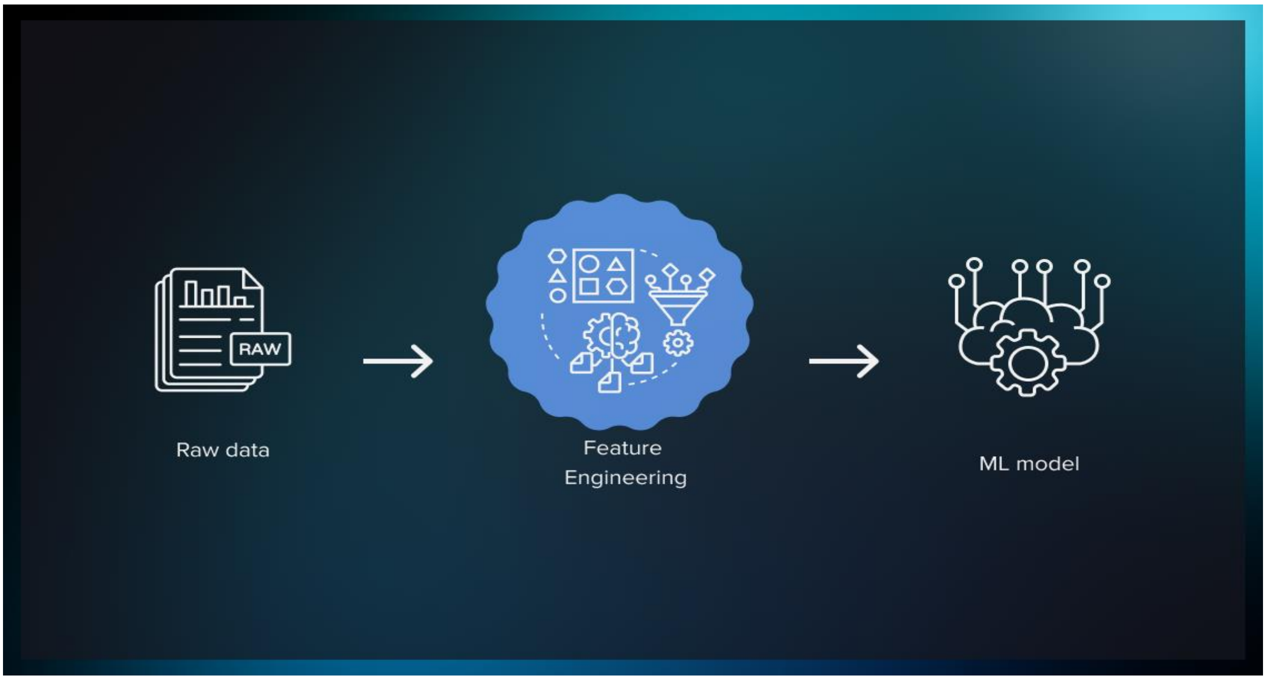

Fig.4 FEATURE ENGINEERING

International Journal of Engineering Research & Technology (IJERT)
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2.4 Data Split

To facilitate software-based model development and evaluation, the digital dataset was partitioned into three key subsets:

Training Set: This segment formed the cornerstone for machine learning model training. It served as the platform for the model to learn the intricate relationships between selected software-engineered features and energy consumption.

Validation Set: The validation subset played a pivotal role in hyperparameter tuning. It was instrumental in optimizing the model's predictive performance.

Testing Set: Comprising unseen data, the testing set was crucial in rigorously assessing the model's predictive capabilities and real-world applicability as per below fig-5.

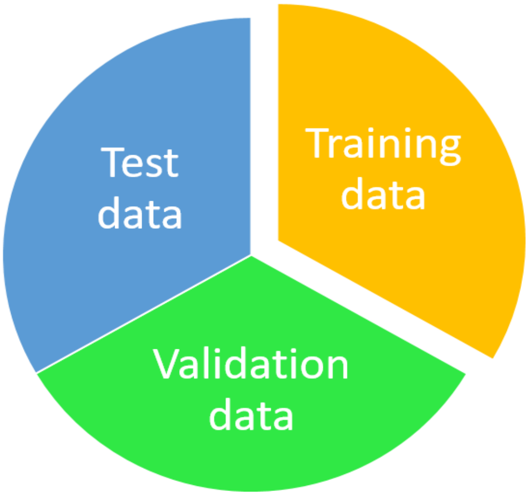

Fig.5 DATA SPLIT

3. MODEL SELECTION

In a software-centric approach, the emphasis shifts to digital data sources and the software-driven methods for data collection and pre-processing. The subsequent sections would delve into model selection, training, evaluation, and the overall methodology specific to this approach as per below fig-6.

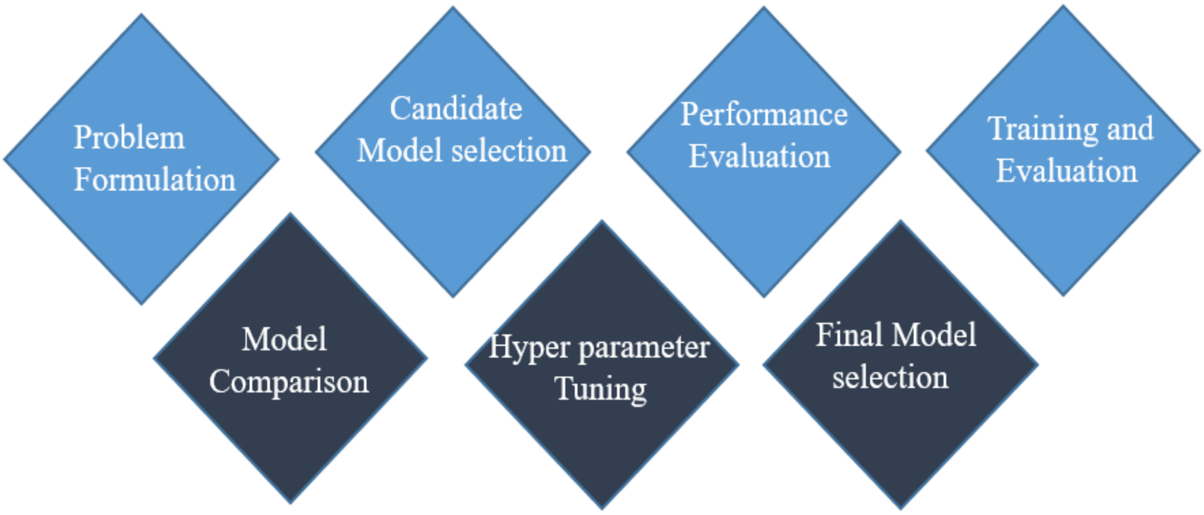

Fig.6 MODEL SELECTION

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4. MODEL TRAINING

Training the Model: The machine learning model was trained using the training dataset to understand the relationship between the selected features and individual energy consumption.
Hyper parameter Tuning: Fine-tuning of model hyper parameters was conducted to optimize the model's predictive performance as per below fig-7.

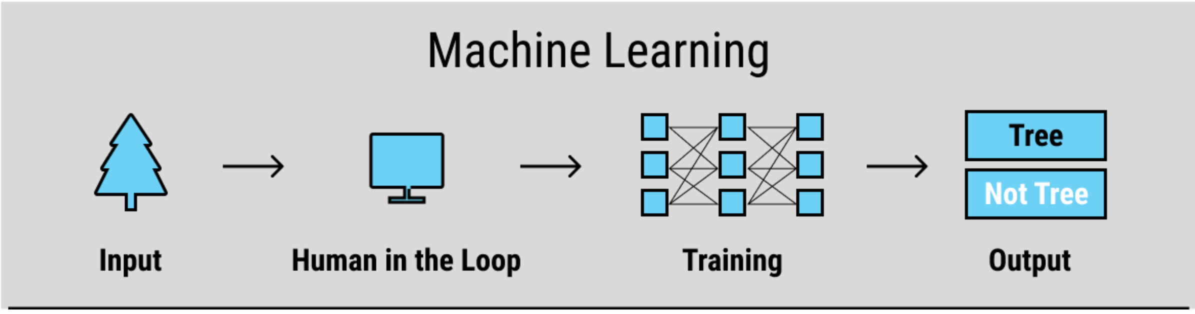

Fig 7 MODEL TRAINING

5. MODEL EVALUATION

Evaluation Metrics: The model was evaluated using common regression evaluation metrics, including Mean Absolute Error (MAE), Mean Squared Error (MSE), Root Mean Squared Error (RMSE), and R-squared (R2) score and the model evaluation techniques are mentioned as below

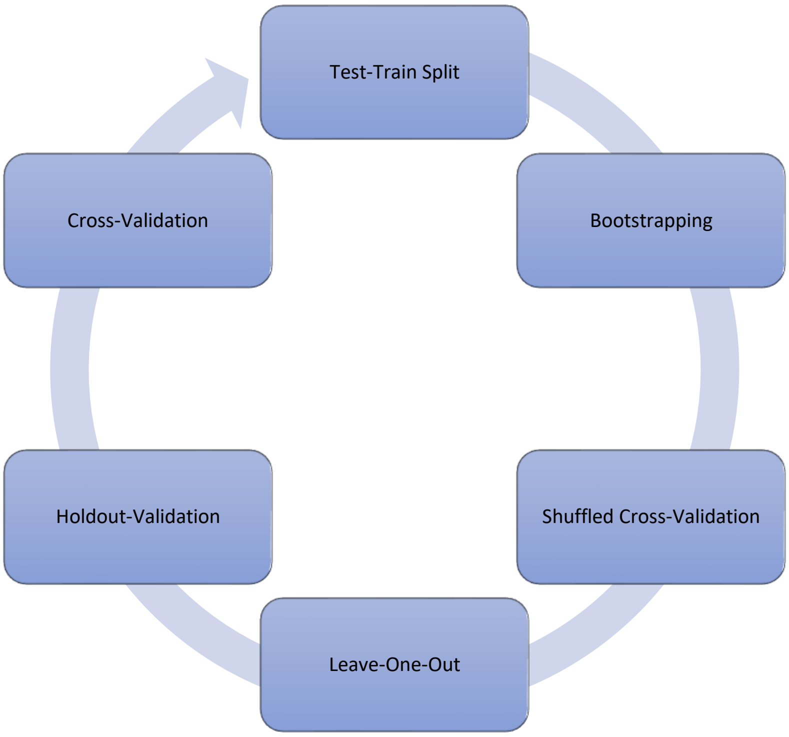

Fig 8 MODEL EVALUATION

6. MODEL TESTING AND DEPLOYMENT

Application to Testing Data: The model's performance was assessed using the testing dataset to gauge its generalization to new, unseen data.
Model Deployment: The trained model was deployed to provide individualized energy consumption predictions, which can be used by consumers and utility companies as per below fig.9.

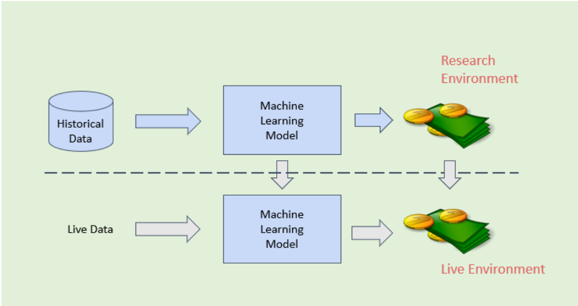

Fig 9 MODEL TESTING AND DEPLOYMENT

7. RESULTS & DISCUSSION

The results of the study, as well as their implications and limitations, were discussed. The potential for future research directions, such as incorporating advanced machine learning algorithms and expanding the dataset, was also considered. An APP is designed in connection with Predicting Individual Energy Consumption. Upon entering the details of an individual it shows the prediction as displayed in fig-10

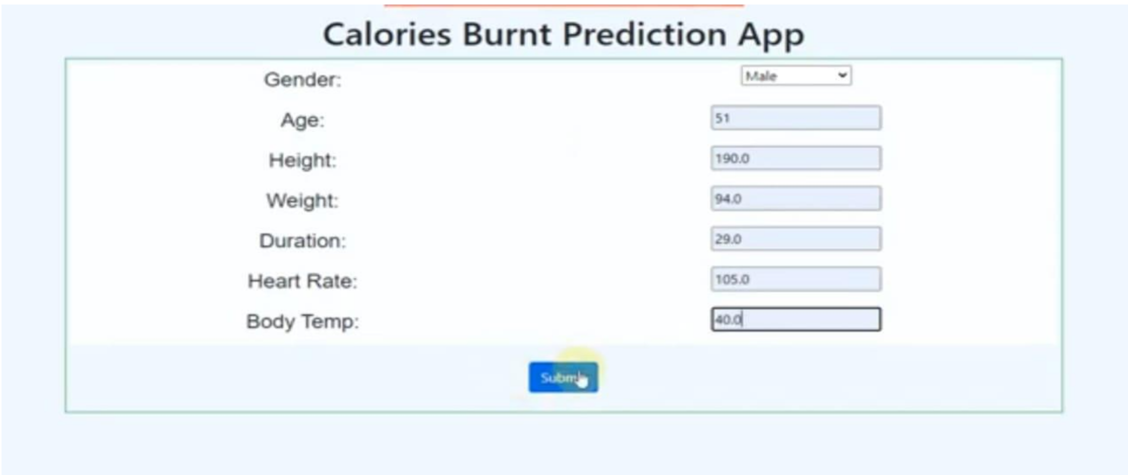

Fig 10

8. CONCLUSION

In this software-driven approach to data collection and pre-processing, the foundation is laid for the accurate and interpretable prediction of individual energy consumption. The meticulous curation of digital data sources and the application of software-based methods for cleaning, feature engineering, and partitioning are instrumental in ensuring data reliability and the creation of a robust dataset. As we move forward into the model development phase, these preparations will serve as the building blocks for constructing a machine learning model that will empower individuals and utility companies with valuable insights into energy consumption patterns, optimizing resource allocation, and reducing environmental impact.

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