Smart Home Energy consumption Prediction Using Machine learning and time series models

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Abstract

The rising electricity demand, escalating energy costs, and sustainability of the environment have given emphasis on the necessity of smart energy management systems in the residential setting. Smart houses have smart meters, sensors, and interconnected appliances that produce constant information on energy usage. Nonetheless, such data is mostly not used because the effective, explained, and lightweight analytical systems are unavailable. The proposed project is a lightweight machine learning based short-term energy consumption prediction framework in smart homes, that will help optimize energy consumption without causing significant costs in terms of resources required to run it on a low resource basis. The main aim of the proposed structure is to accurately forecast the short-term household electricity consumption on the hourly basis using the consumption patterns in the past and the contextual environmental issues. The system has a systematic pipeline that includes data preprocessing, feature engineering, model training and performance evaluation. Preprocessing of data involves normalization of timestamps, treatment of missing time values (time-based interpolation), resampling to even hourly intervals and features scaling. Individual features are also added in feature engineering using lagged consumption values and the time features which improves the potential of the model in capturing the time specific patterns. Several predictive models are applied and tested aiming at trade-offs between accuracy and computation efficiency. They are Linear Regression, Decision Tree Regressor, AutoRegressive Integrated Moving Average (ARIMA), and long short-term memory (LSTM) neural networks. Linear Regression can be used as a base because it is simple and easy to interpret whereas the Decision Trees are used to represent nonlinear relationships in the data. ARIMA is applied in forecasting of univariate time-series as a model to capture temporal variation in energy consumption. LSTM model, which is trained based on cloud-based computing resources, records the long-term time dependency and intricate sequential associations. Mean Absolute error (MAE) and Root Mean Squared Error (RMSE) are used to measure model performance. The outcome of experimental studies proves that lightweight models like Linear Regression and Decision Trees can also be used to obtain competitive prediction accuracy at a much lower computational cost than deep learning models. The LSTM model is very useful in capturing complex temporal behaviour, but it has more computational demands that would restrict its application in resource-constrained smart home systems. ARIMA gives predictable short-term forecasts but limited by the fact that it is univariate. The framework is developed in Python and employs well-known packages such as Pandas, Scikit-learn, Statsmodels, TensorFlow/Keras, and Matplotlib to implement the proposed framework. The modular design has guaranteed scalability, interpretability and easy deployment. Comprehensively, the presented work indicates that it is possible to model the effective prediction of short-term energy consumption with the help of lightweight machine learning models and implement cost-effective, sustainable, and intelligent energy management in smart home settings.