Energy Consumption Prediction Using Machine Learning With State-Based Appliance Features Identified by Design of Experiments

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Unreliable electricity and power outages significantly impact the lives of an estimated 3.5 billion people, primarily in developing nations. The Demand Response (DR) concept optimizes electricity delivery by predicting household energy consumption. However, prediction remains a challenge for state-based appliances (i.e. washing machines) whose energy consumption varies for different states of their process. In this DR-inspired project, an Artificial Intelligence (AI) framework is introduced that (i) utilizes statistical Design of Experiments to study how state-based factors affect energy consumption, (ii) conducts feature engineering to represent statistically significant factors, and (iii) builds machine learning prediction models based on derived features. In a washing machine case study, the statistical analysis of two complete factorial experiments motivated six features characterizing the first energy peak in the washer energy signature. Time localization, power averaging, and interpolation on year-long washer data from IoT sensors yielded 1,543,755 training points. Custom maxima approximation with interquartile range and mean parameters enabled automatic detection of the first peak in longitudinal data. A Best-Subset Regression Model with optimal features and a curvature transformation modeled energy prediction. A Multilayer Perceptron Neural Network (NN), leveraging Bayesian Optimization for optimum hyperparameters and structure, predicted cycle consumption. Prediction with Regression and NN reflected a low relative error of 3.4% and 2.8%, respectively. The presented AI framework addresses a research gap in state-based appliance energy consumption prediction, increasing grid stability during peak demand and mitigating the negative impacts of electricity shortage.

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