Partial Hierarchy Appliance Modelling In Household Energy Consumption

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Introduction

- A smarter energy grid can be a cheaper energy grid as it can play into the supply demand curve more efficiently [1].
- Energy consumption models often represent a non hierarchical model or a total hierarchy in which every device is modeled separately. A partial hierarchy can save on computing times while still being able to extract difficult signals to model them individually.
- The energy consumption problem can be viewed as a time series forecasting issue. This allows us to apply Auto-Regression Moving Average, ARMA, models and its variations ARIMA, SARIMA, ARIMAX

Research question

Can the forecast accuracy for a single household be improved by using a partial hierarchical structure when using an ARMA based method?

Experiment

Pecan Street [2] has provided the data and we utilized their 15 minute New York data set. A partial hierarchy is a model in which only some of the appliances in a household are modeled separately from the house. The rest of the house is still modeled as a singular signal to be predicted.

First a non hierarchical model is constructed to act as a baseline. Then a partial hierarchy is constructed for each device present in a house. These models will then be asked to forecast the next 24 hours of a 7 day input test set. These forecasts are compared to the reference solution for MAE, MAPE, MRE, MRSE scores.

Results

The table below shows the results when running the models in the left column in a non hierarchical fashion. MRE = Mean Relative Error. All other critics are standard, lower scores is better.

	MAE	MAPE	MRE	RMSE
Moving Average	0.30631	178	0.00262	0.52721
ARIMAX	0.31913	197.94	0.00679	0.52979
Persistence	0.33915	178.03	0.00199	0.66903
ARIMA	0.33785	228.4	0.03491	0.55112

Introducing the partial hierarchy as a blanket solution leads to an improvement in 56% of cases. This was reduced to only 16% when taking into account a 5% error margin. However, when only taking the best performer of the category only 27% of cases saw a partial hierarchy as the winner, 8% of cases when considering the error margin. Out of the best performers the winner was moving average with 43% of categories won.

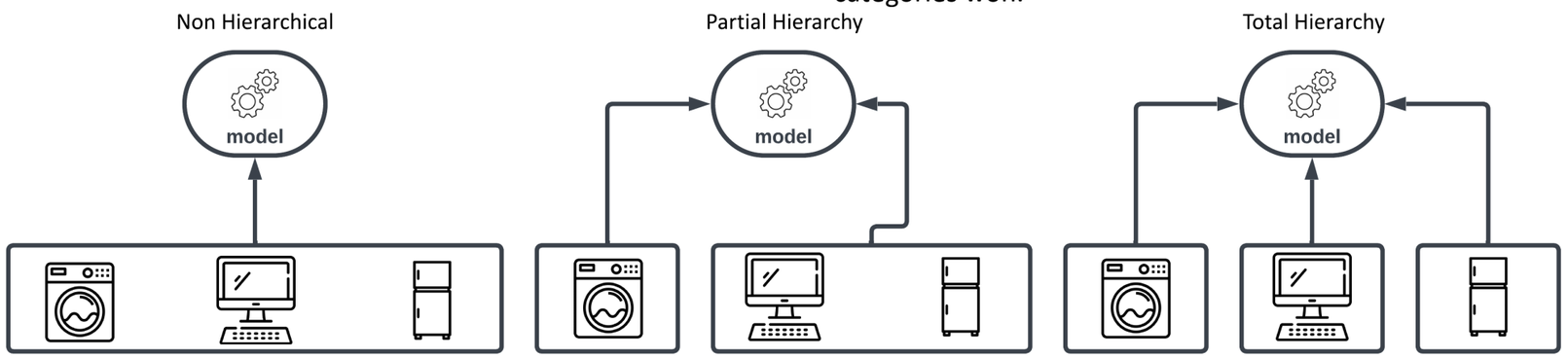

Figure 1: the difference between a Non Hierarchical, Partial Hierarchy and Total Hierarchy model.

Conclusion

- The partial hierarchy model has **no confident improvement** over a regular non hierarchical model.
- ARMA based methods were deemed **unfit** in general to be applied to household energy consumption forecasting.
- It is unrealistic to apply SARIMA to hourly data due to its long fitting time.

Discussion

- The partial hierarchy structure might still be more compatible with different model types and should therefore not be ruled out completely.
- Error margin was set at 5% for a confident improvement yet not all critics respond equally to such a comparison, e.g. MSE & RMSE.
- The research in this area is privacy sensitive. While these techniques could be exercised locally we should remain vigilant with large energy providers attempting to model our behavior.

Future research

- A new type of model should be considered as ARMA has proven rather ineffective at forecasting household energy consumption.
- One could model the device in the partial hierarchy with a different technique that benefits that specific device.
- Finally, consider different scoped data sets, the household sector is very stochastic and these techniques might benefit more being utilized in an office space.

[1] Blumsack, S., & Fernandez, A. (2012). Ready or not, here comes the smart grid! Energy, 37(1), 61–68. https://doi.org/10.1016/j.energy.2011.07.054
[2] PECAN STREET – Pecan Street Inc. (2022, August 23). Pecan Street Inc. https://pecanstreet.org/

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