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Residential appliance identification and consumption prediction for better distribution grid management

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Abstract

A better distribution grid management is based on more local information on consumption patterns. Focusing on buildings (residential or tertiary), two main steps are to be considered. First, identify the particular electrical appliance usage(s) from the meter panel energy reading without being too intrusive in the inhabitant's day-to-day life. Second, predict the future consumption of specific appliances (especially the ones that can be remotely controlled) in order to adapt the (local) production accordingly. Therefore, appliance usage(s) identification and prediction from the meter panel energy reading has become an area of study in its own right and will be assessed in this work.
Unlike many other existing approaches based on signal processing at a high sampling rate, (1 second typically) the proposed approach tries to identify the usage of high power consuming appliance(s) by using the aggregate energy consumption at 10 minutes interval from the meter panel. The proposed approach is then both practical and affordable, without causing any privacy issue. The novelty of the approach lies in using a time series windowing approach which gives additional information about an aggregate energy state. The usage of specific inputs for the algorithms allows taking into account the temporal behavior of residential users. The usage of Multi label classification approach for identification is also new for this domain. The identification and prediction algorithms are tested over a data set of 100 houses monitored over one year.

Keywords: Smart Grids ; Distribution Networks ; Non-intrusive load monitoring, Multi-label classifier, Appliance usage prediction, Energy Management, Data-mining, Smart Homes.

Buildings (residential and tertiary) represent the first energy consumer and the second greenhouse emission source in France. Passive house and positive energy houses are being accepted as a standard for new buildings where the electrical part of energy consumed will be predominant. In order to achieve this goal, energy management have to be set including energy use, meteorology, inhabitant's comportment, etc. But these optimizations of energy savings can contradict an optimal comfort of the habitants. Load management allows

inhabitants to adjust power consumption according to expected comfort, and allows DSO to work on energy price variation in order to reduce economical (or environmental) costs, to increase local renewable integration, etc. It is then of great interest to be able to identify the usage of each appliance because, regarding dynamic demand side management, it is
important to evaluate how much energy can be saved thanks to requests to customers like unbalancing requests or energy price variations. The energy savings depend on appliances: some can be postponed and some cannot be shaded. From a smart grid point of view, the task requires the identification of the total load into its constituent components and then future usage prediction of the appliances.
The primary approach of load separation is based on identification of state transitions which in most cases is done by the ON/OFF transition identification. Prediction of appliance usage is based on appliance consumption data (received after identification), time of the event and meteorological information.

1. Problem definition

The identification model tries to formalize appliance identification by using a temporal windowing approach where the only input after the training phase is the time stamped aggregate power from the power meter. The time is represented as hour of the day. In figure 1 the identification architecture is shown.
The classifier system both for load identification and future usage prediction is based on temporal classification of standard propositional machine learning algorithms. In order to model the time dependency it creates copies of the target field that are shifted in time and generate the sub-sequences. Instances containing these sub-sequences and the current target value are presented as standard propositional instances to the underlying classifying algorithm. This process effectively removes the time dependency in the original target since this is captured by the shifted attributes which is essentially a sliding window.
The work presented in this paper is based on a problem representation in a way that it can be understood by propositional concept learners. Meat-features are defined in order to increase the precision of the identification and the prediction. The definition of these meta-features is one of the key of the algorithm efficiency. Figure 2 proposes different meta-features definition in a sliding time window.

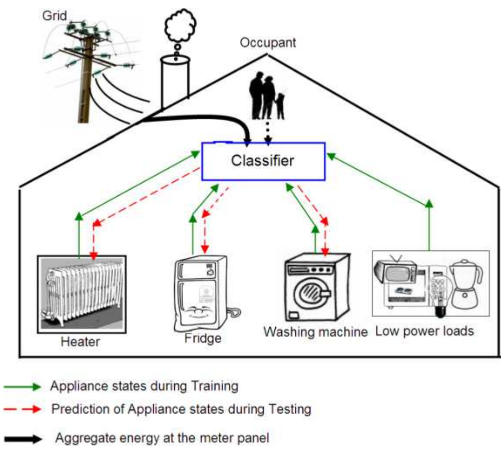

Fig. 1. Classifier architecture

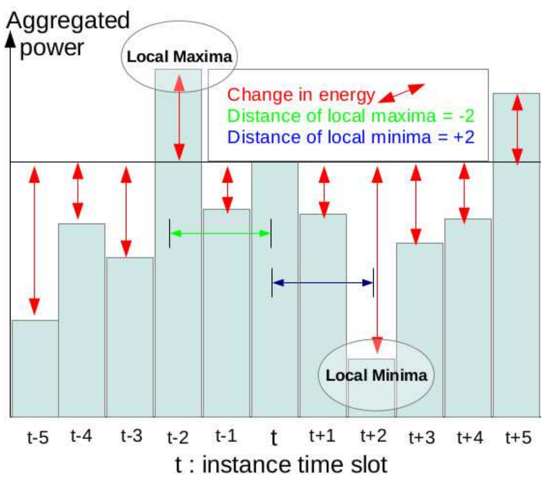

Fig. 2. Different meta-features concerning the aggregated power measurements in a sliding window

2. Load identification and appliance usage prediction

The future usage prediction based on iterative learning approach is proposed taking into account consumption data, time of the event and meteorological information. Figure 3 shows the prediction architecture.

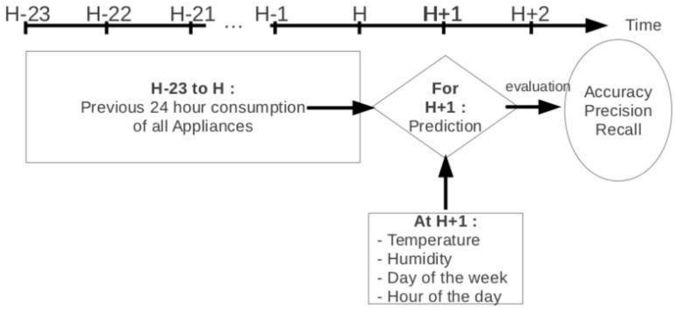

Fig. 3. Proposed Model at a given time instance

The future usage prediction based on iterative learning approach is proposed taking into account identified state, time of event and meteorological information. In this work, the future appliance usage when the individual consumption load is known is compared with the appliance usage after it has been identified at the smart-meter, i.e. based on the previous identification. Results using Label Powerset (LP) algorithm which takes inter-appliance co-relation and Binary Relevance (BR) algorithm are shown in Table 1.

Table.1. Results of appliance usage prediction, based on not on previous identification

Appliance	Algorithm	Based on identification (Smart Meter)			no previous identification (direct connection)		
		Accuracy	Precision	Recall	Accuracy	Precision	Recall
Washing Machine	LP	95.11	66.66	18.66	96.58	90.74	64.42
	BR	95.13	60.51	28.22	96.61	90.00	65.57
Microwave Oven	LP	88.22	13.33	1.41	90.47	32.83	2.75
	BR	88.27	0	0	90.40	35.92	4.62
Water Heater	LP	95.71	83.42	81.68	98.73	96.29	93.29
	BR	95.96	86.16	80.33	98.73	96.29	93.29
Dish Washer	LP	95.94	0	0	98.96	83.67	33.60
	BR	95.94	0	0	99.00	86.00	35.24

The results in Table 1 indicate the appliances which can be identified with high accuracy and precision can also be better predicted for future usage consumption. In our case the water heater can be predicted with higher accuracy because it was identified with high precision. As only high energy consuming appliances are used for prediction, the inter-appliance dependence is not reflected in these results. So both the algorithms give similar performances. But previous results show strong indication of inter-appliance dependence. The fact that some appliances have high accuracy but low precision and recall (sometimes zero) is due to the dataset being highly sparse and it being representative of only the ON class. Indeed, most of the high energy appliances are OFF most of the time.

References

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