ICT With Industry Report - Case 4: Homie

Abstract

Homie introduces the Pay-Per-Use model for whitegoods with the aim of reducing environmental impact of domestic appliances by steering users towards more energy-efficient behaviors and promoting product longevity. To facilitate the growth of the company and expansion beyond the domain of washing machines, Homie needs to be able to deduct user's program choices from energy consumption patterns. Our group analyzed the energy consumption of 64 wash programmes, focusing on the research question whether it is possible to identify the temperature setting from this time series data. With supervised techniques we first examined the correlation between the number of timepoints when the signal has a certain height and the temperature of the washing program. Second, we considered classification using regression, k-nearest neighbor and shapelets (sub-sequences of the time series). Through unsupervised methods, we found that signals in the heating sequence are highly alike and can be extracted. Lastly our group focused on data visualization in the form of dashboarding and reporting. With the dashboard, we made it easier to see for Homie which washing programs are actually efficient, so they are able to adjust their pricing in a data driven manner. Reporting of user's energy consumption behavior may be a promising method for nudging users towards more energy efficient behaviors.

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Introduction

Circular Economy and the Internet of Things are two areas that have been steadily gaining momentum in research, business and politics in recent years. The potential of these concepts lies with delivering sustainability benefits across product life cycles, from raw material extraction through to the end-of-life phase of products.

Utilising the interconnectedness of modern technologies and moving away from the classic ownership model to new, more sustainable business models lies at the very heart of what Homie does. Focusing on reducing the environmental impact of domestic appliances significantly and offering more affordable solutions to the customers, Homie starts from washing machines and transforms the user pattern from “ownership” to “Pay-Per-Use”.

Research questions

Homie’s vision of reducing environmental impact comprises of many aspects. In this project our group specifically aims at end-user behaviour. Thus far the washing bill is determined primarily by the temperature of the program setting. The related information is collected by a built-in tracker and then sent over via Internet. This approach requires the tracker to adapt to every new brand and new model. An alternative external tracker is in development to deal with the generalisability, wherein the electricity power consumption is sampled in the frequency of once per second. Therefore, a time series of power signal is acquired at the end of each wash cycle. Our primary goal is to infer the temperature setting according to the time series signal. Alongside we expand the work in relevant directions based on the same format of input data.

Available data

Homie provided 64 time-series indicating power consumed per second in a wash cycle for different wash programmes. The time series were labeled with wash cycle programme for cotton, wool, darks and jeans along with more details such as temperature, wash load, Eco mode (y/n), Extra rinse (y/n).

Supervised Learning Techniques

With Homie’s labelled data, we tried to build a classification model for different types of washes using supervised learning methods. We tried to answer a two-fold question: What programme is being run and when is the earliest that the wash programme can be correctly classified.
First we worked with simple correlation of timepoints and energy signals and analyse the data using thresholds, rising edges, summing signals, binning and histograms to extract meaningful features. We then used linear regression with these features to predict the temperature of the wash programme. We also looked at shapelets based model, which tries to find sub-sequences in the time series that can be used to predict the wash programs. With all these analysis tools, we built a hierarchical model, where the first 30 minutes of the cycle were used to predict whether the wash programme is a proper wash or a short

spin/rinse cycle with 95% accuracy using KNN based classifier. Further on we predict the wash cycle temperature with 80% accuracy using regression models. Importantly we do not lose the accuracy when downsampling the time series upto 1/10th of the original. Shapelets based model was found to be prone to overfitting, requiring more data to be reliable.

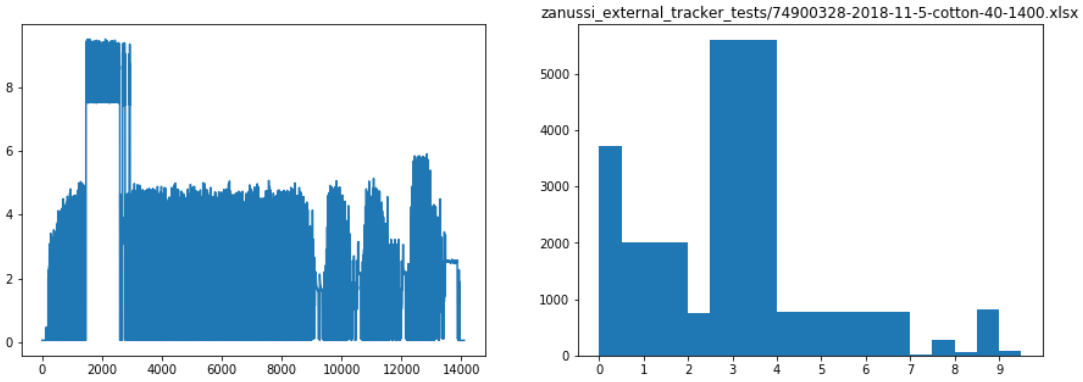

Image 1: Time series of a cotton 40 wash, note the heating part with current between 7 and 10 (left), and its histogram (right).

Automatic recognition of component activity

From the detection of different activity patterns in the power usage, the different stages of the washing cycle may be identified. The identification of the stages and their duration may yield useful information for determining the specific washing program that has been selected. It has also numerous other usages for predictive maintenance. It can reveal anomalies in the power usage of specific components indicating component failure.

In order to recognize different stages in the power usage, we have used a hierarchical clustering method that compares segments of the timeseries to each other, grouping similar segments in clusters and dissimilar segments should lie in different clusters. There are various measures that determine the quality of the clustering. Based on these measures, we have determined that the optimal number of clusters is around five. However, there are various other parameters used that need further tuning to reach more optimal results. This is expected to significantly improve the automatic recognition of stages in the wash cycle.

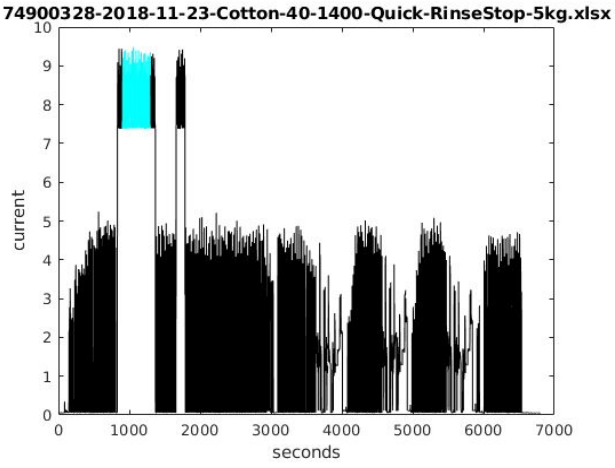

Image 2: Example of a cluster, here we can clearly see that the heating cycle is recognized.

Dashboard

HOMIE wants to encourage users to use a washing program which is environmentally friendly. Since the temperature of the wash seems to be a good indicator of its energy usage, this is now the main factor when deciding the price for a program. Since it is expected that the *ECO* setting makes a wash more environmentally friendly, users get a discount for using this setting. To investigate whether other settings influence the energy usage as well, we made a Dashboard to explore the measured washing cycle. Here a user can select an upperbound and lowerbound of total current consumed in the washing cycle, ranging between 0 and 60.000 ampere. The user then gets a summary of all the washes in this range. Using this, we find some interesting observations. First of all, it seems that all of the washes using the ECO mode appear in the mid-range of usage. Second of all, most of the washes using an Extra Rinse cycle appear in the upper-range. Lastly, most Half/Quick washes appear in the lower-range. This makes one reconsider the current pricing. When available, this dashboard could be extended to include actual user data, and then categorize the data per user. This would also make it easy to explore efficient/non-efficient users.

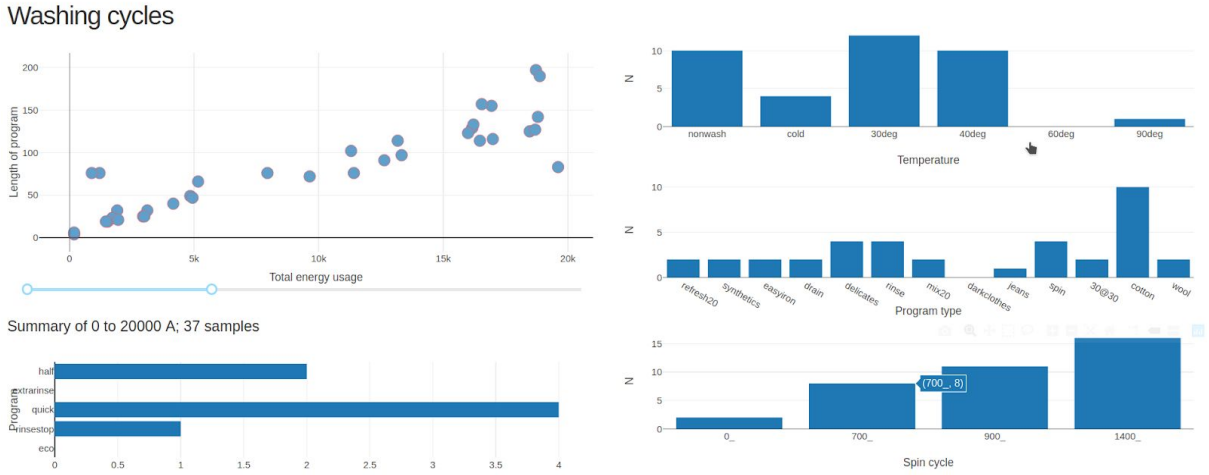

Image 3: Screenshot of dashboard, where we can see on the left side: The scatterplot of usage vs length, the slider to select range and the programs. On the right side; the temperature setting, program setting and spin cycle.