

Bayesian Neural Networks on the Inference of Distillation Product Quality

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Abstract

This paper applies Bayesian neural networks on the inference of diesel 85% ASTM distillation, and compares the results with traditional multi-layer perceptrons.

Introduction

The control of the distillation process in oil refineries requires the evaluation of product quality throughout the operation of the plant. This paper uses Bayesian neural networks, combined to several pre-processing and variable selection techniques, to develop systems for inference of the quality of distillation products, for REPAR refinery (Refinaria do Paraná), operated by PETROBRAS S.A.

Methodology

A set of 81 sensors are distributed along the plant. The experimental data consisted of one value per minute, yielding 1,440 values per day, in a total of 780,480 values. The output variable is the temperature of Diesel 85% ASTM distillation, in a total of 1,811 values, divided in 576 for training, 384 for test, and 851 for validation. We normalized the sensor data by using the nominal range of measurements for each sensor. Also, we calculated an average of the input variables, weighted by the cross-correlation function. Three methods for variable selection have been tested: Principal Component Analysis (PCA), Cross-correlation (CORR) and Automatic Relevance Determination (ARD). The latter, a by-product of the training process of Bayesian neural networks (BNN), provides the best results. BNNs are inspired by Bayesian statistics, using probability densities instead of frequencies. It assumes a particular model for the probability densities of data and network weights, and uses Bayes' rule to infer the optimum weights, given the available data [1]. Also, in this work we took the ARD method one step further, effectively removing the input variables with the smallest relevances.

Results

Two neural network algorithms have been tested: backpropagation multi-layer perceptrons (BPMLP) [2] and BNNs [1]. The networks have log-sigmoid activation functions, one output neuron and one hidden layer, with the optimum number of hidden neurons found empirically. Table 1 presents the train and test MAPE errors for the BPMLP and BNN networks, considering the three variable selection techniques.

Table 1 – Best results obtained with backpropagation and bayesian neural networks.

Variable Selection	# input variables	# hidden neurons	MAPE train	MAPE test
Backpropagation Neural Networks				
PCA (95%)	17	3	2.169%	3.328%
ARD (1%)	6	1	2.083%	1.604%
CORR	6	1	2.374%	1.806%
Bayesian Neural Networks				
PCA (95%)	17	5	2.442%	2.578%
ARD (1%)	6	1	2.109%	1.603%
CORR	9	3	2.199%	1.690%

Conclusion

The best inference was obtained using a one hidden neuron bayesian neural network with six input variables, ARD variable selection and weighed averaging. Fig. 1 presents the network outputs for validation patterns. The largest errors are negative, corresponding to large decrements in product quality. This was to be expected, due to the direction dependency of the distillation process [3].

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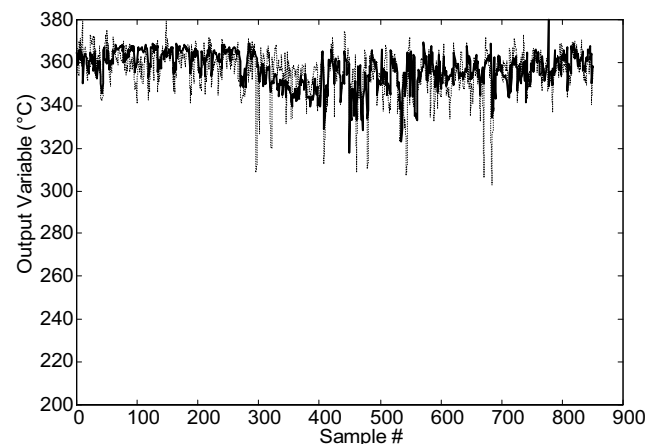


Fig. 1. Validation of the best network trained (solid line). The dotted line corresponds to the actual variable values.