NEURAL NETWORKS MODEL OF MOTHER LIQUOR PURITY OF C MASSECUITE

By

C. BONNECAZE, B. GRONDIN-PEREZ, M. BENNE and J.P. CHABRIAT
Faculty of Sciences and Technologies, University of La Reunion

Abstract

Crystallisation is an important stage in the manufacturing process of sugar cane. In Bois Rouge sugar mill, the crystallisation process is performed in three stages. Our work deals with C crystallisation. During crystallisation, purity of mother liquor is a parameter of importance as it indicates the concentration of sucrose remaining in solution. The final productivity of the sugar cane conversion is dependent on the efficiency of C crystallisation. In Bois Rouge sugar mill, no physical measure is available concerning exhaustion on-line in C crystallisation. To observe the dynamic exhaustion of mother liquor during the growing stage, we took samples of molasses and massecuite every ten minutes. These samples were analyzed to determine purity of mother liquor. Then, we built a multi-step predictor of mother liquor purity using physical measures on-line and off-line. First results are very encouraging.

Introduction

The sugar cane industry is the most important industry on Reunion Island. So the control of the whole process of sugar production is of great economic importance. The crystallisation process is the final step of sugar production. Consequently, sugar quality and productivity are greatly dependent on an efficient control of operating conditions. In Bois Rouge sugar mill (B.R.), sugar crystallisation is performed in three steps. The final one named C crystallisation is the ultimate stage where the sucrose in liquid form can be converted into a solid form. In order to follow the performance of this conversion, we decided to model the behaviour of the C mother liquor purity during the growing stage of C crystallisation.

For some 15 years, there has been an increasing interest in the Artificial Neural Networks (ANN) theory in the domain of control engineering. The main interest of ANNs is in their universal approximation properties (Funahashi, 1989; Hornik et al., 1989), as well as their ability in modeling noisy or likewise incomplete data. The aim of this study is to show the performance of neural networks in modeling the C crystallisation process.

The crystallisation process

Downstream from the evaporation process, the final step in the manufacture of sugar cane is the transformation of 70 Brix syrup into crystals. This operation is achieved stage-wise, to increase performance with minimum energy consumption. At BR, this liquid-solid transformation is performed through a series of semi-batch vacuum evaporation pans. The C mother liquor purity gives information about the concentration of sucrose remaining in solution. It depends on the state of the mother liquor (i.e. the thermodynamic state). The state variables can be measured by the temperature (i.e. the vacuum: \( V_c \)), the massecuite level in the pan (L) and the mother liquor brix (\( B_{ml} \)). During the growing phase, the pan is fed with B molasses. So, it seems wise to take the input feed (\( \dot{Q}_B \)) and the purity of B molasses (\( P_B \)) into account in the inputs of the model.

Neural networks technology

The most interesting property of ANNs is their capability to define an internal model of non-linear functions from input and output samples. The neural model can be defined as a non-linear function parameterised with a set of weights. The identification methodology is similar to these used for classical models. The network is made up of a set of layers composed of similar units called neurons or nodes. Each unit represents a simplified processing cell, which computes the non-linear function \( f_{NL} \) of the weighted sum of input information on the node. The activation function \( f_{NL} \) is the following sigmoidal function:

\[
    f_{NL}(x) = \frac{1}{1 + \exp(-x)}
\]

We performed our works using a feedforward network. This network can be compared to a transverse non-linear filter (Marcos et al., 1992) which defines an output \( y(k) \) by:

\[
y(k) = f_{NL} [\Theta, X(k)]
\]

with:

\[
    X(k) = [x_1(k - 1), x_2(k - 1), ..., x_n(k - 1)]^T
\]

where

\[
    X(k) = [x_1(k), x_2(k), ...] \quad \text{is the observation vector symbolising the data reaching the input cells at the instant } k;
\]

\( y(k) \) is the output calculated by the network; \( s(k) \) is the output of the process to model;

\[
    \Theta = [\Theta_1, \Theta_2] \quad \text{the weighting coefficient of the different connections which represent the neural network parameters.}
\]
The data

B.R. sugar mill is equipped with a supervision and control system. The variables describing the industrial processes are collected by a set of peripheral devices connected to one another through a Programmable Automaton Coupler (PAC). So as to interface the processes and a PC, we have developed the data server I-MEDIA which communicates with the PAC to collect the data.

The model structure

We developed a non-linear model of C mother liquor purity which can be written as:

\[
P_{\text{ml}}(k) = F_{\text{ml}}(P_{\text{ml}}(k-1), B_{\text{ml}}(k-1), Q_s(k-1), V_s(k-1), P_s(k-1), L(k-1))
\]

Where \(P_{\text{ml}}(k)\) represents the C mother liquor purity predicted at sample \(k\). The parameters fitting is achieved by minimisation of a cost function \(J(k)\) defined as modeling squared error at the time \(k\) and given by:

\[
J(k) = (P_{\text{ml}}(k) - \hat{P}_{\text{ml}}(k))^2
\]

Where \(\hat{P}_{\text{ml}}(k)\) is the offline measured value. The parameters are updated after the processing of each sample contained in the database. The learning is achieved with an iterative and recursive algorithm. It is based on the computation of the stochastic gradient of \(J(k)\) versus \(\theta\).

The validation step

In order to estimate the identified models quality, a great number of tests have been suggested (Billings and Voon, 1986; Pottman and Seborg, 1992). Only the mean of the sum of the squared error (MSSE) between the calculated output \(y(k)\) and the output of the process \(s(k)\) has been used. Subsequently, the modeling issue being to use these models in predictive control algorithms, the mean of the sum of squared error written MSSE is calculated with the closed loop predictor (parallel type): the past calculated outputs and the inputs applied to the process are then supplied in the formula:

\[
\hat{P}_{\text{ml}}(k) = F_{\text{ml}}(P_{\text{ml}}(k-1), B_{\text{ml}}(k-1), Q_s(k-1), V_s(k-1), P_s(k-1), L(k-1))
\]

When the learning stage is achieved, the model parameters and structure are fixed and it can be tested offline on the basis of data measured on line and offline (molasses and mother liquor purity).

The work presented previously is encouraging as the mean error given by the model is less than 0.3 points of purity.

REFERENCES


NEURAL NETWORKS MODEL OF MOTHER LIQUOR PURITY OF C MASSECUITE

C. BONNECAZE, B. GRONDIN-PEREZ, M. BENNE et J.P. CHABRIAT
Faculty of sciences and technologies, University of La Reunion

Résumé

La cristallisation du saccharose est une tape importante dans le processus de transformation de la canne sucre. Afin d’épuiser au maximum une solution sucrée, il est courant de procéder à une cristallisation fractionnée. À la sucrerie de Bois Rouge, la cristallisation met en œuvre le procédé des trois masseculites. Pendant la cristallisation, la pureté de la liqueur mère est un paramètre important puisqu’il indique la concentration des molécules de saccharose solubles. Du point de vue du rendement de la transformation de la canne à sucre, la cuite C constitue la dernière étape au cours de laquelle les molécules de saccharose peuvent être extraites de la liqueur mère. Sur le site de Bois-rouge, aucune mesure physique ne permet de quantifier l’épuisement tout au long de la cuite. Pour pouvoir observer la dynamique de l’épuisement de la liqueur mère nous avons prélevé toutes les 10 minutes des échantillons de massecuite et d’égout d’alimentation pendant la phase de montée. Ces échantillons ont ensuite été analysés, permettant ainsi d’estimer la pureté de la liqueur mère. Sur la base des mesures réalisées sur le procédé et des puretés déterminées par analyse, nous avons construit un prédicteur de pureté liqueur mère dont les performances sont encourageantes.
UN MODELO DE REDES NEURONALES PARA LA PUREZA DEL LICOR MADRE DE LA MASA COCIDA C

C. BONNECAZE, B. GRONDIN-PEREZ, M. BENNE y J.P. CHABRIAT
Facultad de Ciencias y Tecnologías—Universidad de la Reunión

Resumen
La cristalización es una etapa importante en los procesos de manufactura del azúcar de caña. En el ingenio azucarero de Bois Rouge la cristalización se lleva a cabo en tres etapas. Nuestro trabajo se efectuó con la cristalización C. Durante la cristalización la pureza del licor madre es un parámetro importante ya que indica la concentración de sacarosa remanente en la solución. La productividad final de la conversión del azúcar de caña depende de la eficiencia de la cristalización C. En el ingenio de Bois Rouge para observar la dinámica del comportamiento del licor madre durante la etapa de crecimiento se tomaron muestras de mieles y masas cocidas cada diez minutos. Estas muestras fueron analizadas para determinar la pureza del licor madre. Posteriormente se construyó un predictor multietapas para la pureza del licor madre utilizando mediciones físicas en y fuera de línea. Los primeros resultados son muy estimulantes.

Palabras claves: Redes neuronales, licor madre, masa cocida C.