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Research Paper

FUZZY NEURAL NETWORK MODELLING AND pH VALUE CONTROL IN THE CLARIFYING PROCESS OF SUGAR CANE JUICE

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Nowadays, neural network technologies are emerging as the technology choice for many applications, such as patter recognition, prediction, system identification and control. Neutralizing pH value of sugar cane juice is the important craft in the control process in the clarifying process of sugar cane juice, which is the important factor to influence output and the quality of white sugar. On the one hand, it is an important content to control the neutralized pH value within a required range, which has the vital significance for acquiring high quality purified juice, reducing energy consumption and raising sucrose recovery. On the other hand, it is a complicated physical-chemistry process, which has the characteristics of strong non-linearity, time-varying, large time-delay, and multi-input. Therefore, there has not a very good solution to control the neutralized pH value. Firstly, in this paper, neural network model for the clarifying process of sugar juice is established based on gathering 1200 groups of real-time sample data in a sugar factory.

Keywords: Clarifying process of sugar cane juice, Neural network, Lab view, Neutralized pH value

INTRODUCTION

The word “sugar” used in everyday life refers to the chemical sucrose. Sucrose is a member of a group of substances generally known as sugars, which contain up to ten monosaccharide Units These, in turn are part of a wider group of carbohydrates which account for 75% of the dry weight of the Plant world. All carbohydrates are compounds built up from the elements carbon, hydrogen and oxygen. All sugars are crystalline, water soluble and sweet tasting. There are mainly two purposes to build the NN model for clarifying process of sugar cane juice. One is the NN model acting as the controlled object, which is simulated in computer before implementation in real-time control. The pH of factory liquors is of considerable importance. Below pH 7 sucrose is hydrolysed to the reducing sugars glucose and fructose, while above pH 9, alkali

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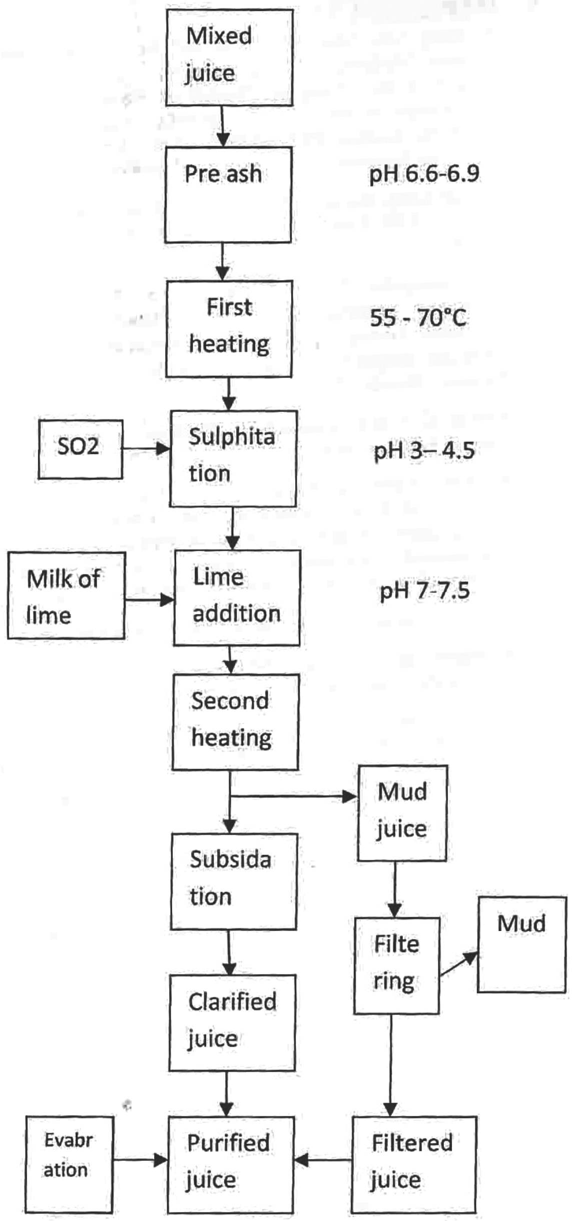
destruction of sugars occurs and coloured components are formed.

WORKING PROCESS OF SUGAR JUICE

At present, sulphurous acid method is very popularly used in most sugar factories in China. In this craft the process of neutralizing the pH value is very important and it directly influences the output and the quality of white sugar. The mixed juice coming from the milling section is processed by working procedures such as predefecation, heating, neutralization reaction, sedimentation and filtering and so on. The aim is to put out the high-quality sugar in the course of crystallization by eliminating the non-sugar elements and eventually obtain the high quality of the granulated sugar. The sulfitation process is mainly adopted at present. It is a complicated physical-chemistry process to clarify the juice, and is divided into four stages which are predefecation, heating, neutralization reaction, sedimentation and filtering, as shown in Figure 1. Clarifying agents commonly used in sugar factories mainly include lime, sulphur dioxide, industrial phosphoric acid, etc. At first a small amount of lime is put into the mixed juices, and at the same time, phosphoric acid is also put into the mixed juices to adjust pH to a low-grade acidity or neutralization. And then the mixed juice is heated, for the first time, with the temperature controlled within the range of 55-70! After that the mixed juice is sent into the neutralization device. In neutralization device, the lime liquid and sulphur dioxide gases are added to mixed juices. Then sulfurous acid and calcium hydroxide neutralize in the join, which produces calcium sulfurous to be separated out, synchronously colloid is

Figure 1: Clarifying Process Flow Diagram



coagulated. Then the neutralized juice is heated for the second time to accelerate reaction of phosphoric acid and sulfurous acid. Finally the neutralized juice is going to the subside for subsiding. The main factors affecting the sulphitation neutralization are:

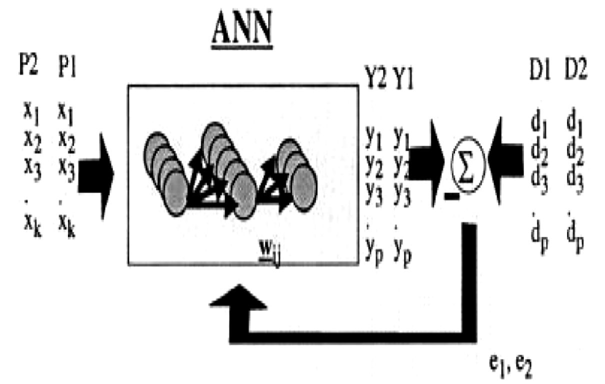
- The instability of flow of juice will directly influence the following operations such as adding lime, sulphur dioxide and the phosphoric acid.

- Either pre-ash's pH value too high or too low will result in the increased difficulty of the sulphitation neutralization control.
- Influence of the lime milk and sulphur dioxide flow. If the amount of lime put into the juice is too small or the amount of sulphur dioxide is too large, pH value in the sugarcane juice will become acid, which will affect neutralization reaction and cause high SO_2 and calcium contents in the purified juice, and inevitably decrease the purity of juice. If too large amount of lime or too small amount of sulphur dioxide is put into the juice, it will cause the reducing sugar resolving and increase Colour Value of the purified juice, and inevitably decrease the purity of juice. It has the vital significance to control pH value stability in the clarifying process of sugar juice, which affects directly the quality of the purified juice, and inevitably the product's quality. If the neutralized pH value is too low, this will speeds up the sucrose transformation, which results in loss of sucrose sucrose and cause the juice containing higher dissoluble calcium, and inevitably cause a lot of scale formed in the evaporation station and boiling house, thus it increases energy wastage. Contrarily, when the neutralized pH value is too high, the original sugar decomposes the new pigment so that its colour becomes depth, these can increase colour value of the product sugar, and affects the quality of the granulated sugar. Moreover, instability of the pH value can increase the amount of use of the clarifying agent, and increase the cost.

NEURAL NETWORK MODELLING PROCESS

A artificial neural network is developed with a systematic step-by-step procedure which optimizes a criterion commonly known as the learning rule. The input/output training data is fundamental for these networks as it conveys the information which is necessary to discover the optimal operating point. In addition, a non linear nature makes neural network processing elements a very flexible system (Figure 2).

Figure 2: The Neural Computation



Basically, an artificial neural network is a system. A system is a structure that receives an input, process the data, and provides an output. Commonly, the input consists in a data array which can be anything such as data from an image file, a WAVE sound or any kind of data that can be represented in an array. Once an input is presented to the neural network, and a corresponding desired or target response is set at the output, an error is composed from the difference of the desired response and the real system output. Artificial Neural Network (ANN) is used in this work for system identification. The data required to develop the ANN model for system identification are collected by conducting experiments in the laboratory grade pH process and through MATLAB simulation. The collected data is divided into training and test data. The sampling instant k is equivalent to *t* and the neural network structure used. Network training is first carried out offline in batch form using the Leven berg-Marquadt optimization.

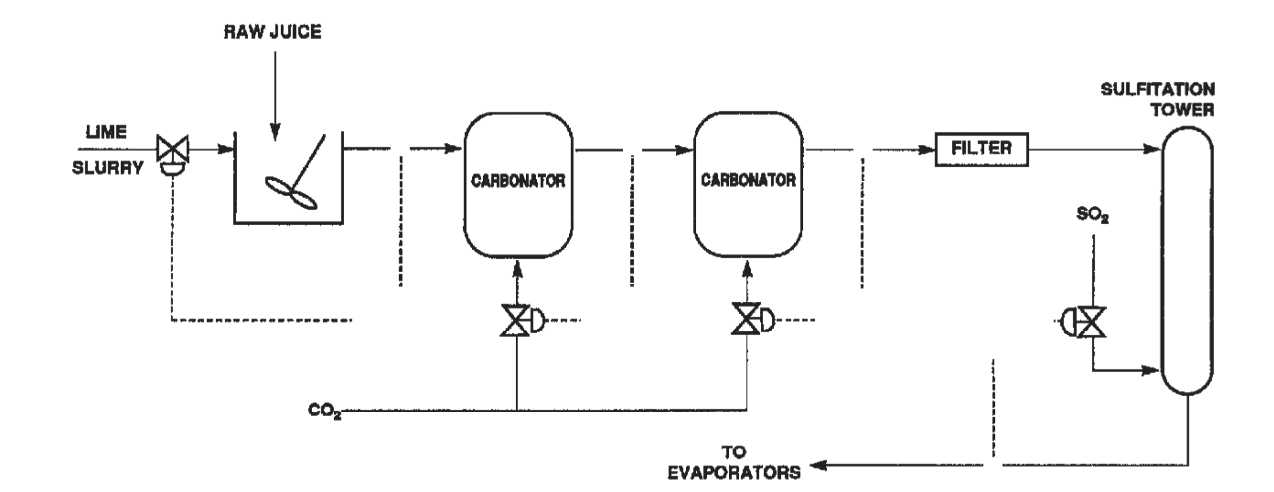
GENETIC ALGORITHMS

Genetic Algorithms provide an adaptive searching mechanism inspired on Darwin's principle of reproduction and survival of the fittest. The individuals in a population are represented by chromosomes; each of them is associated to a fitness value. The chromosomes are subjected to an evolutionary process which takes several cycles. Basic operations are selection, reproduction, crossover and mutation. Parent selection gives more reproductive chances to the fittest individuals. During crossover some reproduced individuals cross and exchange their genetic characteristics. Mutations may occur in a small percentage and cause a random change in the genetic material, thus contributing to introduce variety in the population. The evolution process guides the genetic algorithm through more promising regions in the search space. Some of the advantages of using genetic algorithms are: it is a global search technique, can be applied to the optimization of ill-structured problems and do not require a precise mathematical formulation for the problem. Besides, genetic algorithms are robust, applicable to a number of problems and efficient, in the sense that either a suboptimal or optimal solution may be found within reasonable time.

pH CONTROL IN SUGAR REFINERIES

The sugar is refined from raw sugar cane or beets. The process includes the following steps: wash, crush, extract, treat with lime, carbonate, and filter, add sulfur dioxide, concentrate, crystallize, and dry. The steps in italics are most critical to the final product and require continuous pH control. These are described below. Alkaline "milk of lime" is automatically injected to raise the pH of the raw juice to 11-11.5. Figure 3 shows the pH control in sugar refineries.

Figure 3: pH Control in Sugar Refineries



FUZZY MODELLING

Fuzzy modelling often follows the approach of encoding expert knowledge expressed in a verbal form in a collection of if—then rules, creating a model structure. Parameters in this structure can be adapted using input-output data. When no prior knowledge about the system is available, a fuzzy model can be constructed entirely on the basis of system measurements. In the following, we consider data-driven modelling based on fuzzy clustering. This approach avoids the well-known bottleneck of knowledge acquisition. The fuzzy model is acquired from sampled process data, utilizing the functional approximation capabilities of fuzzy systems. Assume that data from an unknown system $y = F(x)$ is observed. The aim is to use this data to construct a deterministic function $y = f(x)$ that can approximate $F(x)$. The function f is represented as a collection of fuzzy if—then rules. Depending on the form of the propositions and on the structure of the rule base, different types of rule-based fuzzy models can be distinguished TSK fuzzy modelling of clarifying process we consider rule-based models of the Takagi-Sugeno (TS) type. It consist of fuzzy rules which each describe a local input output relation, typically in an affine form. The representation as a TS model is given by

Ri : If *x*1 is *Ai*1 and, ..., and *xn* is Ain then *yi* = *aix* + *bi*

With i = 1, 2, ..., K. Here, *Ri* is the i^{th} rule, *Ai*1, ..., *Ain* are fuzzy sets defined in the antecedent space,

x = [*x*1, ..., *xn*]*T*

is the antecedent vector, and *yi* is the rule output variable. K denotes the number of rules in the rule base, and the aggregated output of the model, ˆ*y*, is calculated by taking the weighted average of the rule consequents.

In general, a classical PID control system can be depicted, in which the input-output relation of the PID controller is expressed as,

$$u = Kce + 1/Tt\int_0^t edt + Tde$$

Where u is the control signal, e is the error signal, and *Kc*, *Ti* and *Td* denote the proportional gain, the integral gain and derivative gain, respectively.

BASIC PSO ALGORITHM

The modification of the particle's position can be mathematically modeled according the following equation:

$$V_i^{k+1} = wV_i^k + c_1\, rand_1(\ldots)x\left(pbest_i - s_i^k\right)$$
$$+ c_2\, rand_2(\ldots)x\left(gbest - s_i^k\right)$$

where,

V_i^k	:	Velocity of agent i at iteration k w: weighting function,
c_j	:	Weighting factor,
rand	:	Uniformly distributed random number between 0 and 1,
s_i^k	:	Current position of agent i at iteration k,
$pbest_i$	:	*pbest* of agent i,
gbest	:	*gbest* of the group.

The following weighting function is usually utilized in

$w = w\text{Max} - [(w\text{Max} - w\text{Min}) \text{ x iter}]/\text{maxiter}$

where,

wMax = Initial weight,

wMin = Final weight,

maxiter = Maximum iteration number,

iter = Current iteration number.

$$s_i^{k+1} = s_i^k + V_i^{k+1}$$

RESULTS

The input and output data sets used for training are obtained by adding a random generator with step input and then applying this to the trained to minimize the cost function The neural network modelling mainly has several important links: sample data pre-treatment, data normalization, network design, network training and network test and so on. When processing the sample data, summarizing the operation range of sampled variables based on technical requirements and operation experiences, parts of the data can be primarily eliminated. After being processed, 800 sets of data are used as training samples, and 200 sets of data are used as testing samples, the data become numerical values between (–1, 1) after a naturalized process. Our designed neural network is chosen as a 4-25-1 structure with 4 input neutrons, 25 hidden neutrons and 1 output neutron. For this neural network, the hidden layer and output layer use the sigmoidal function. We have applied trainlm (the Levenberg-Marquardt algorithm) for the

Figure 4: Modelling Data Output 2-MSE = 0.0131

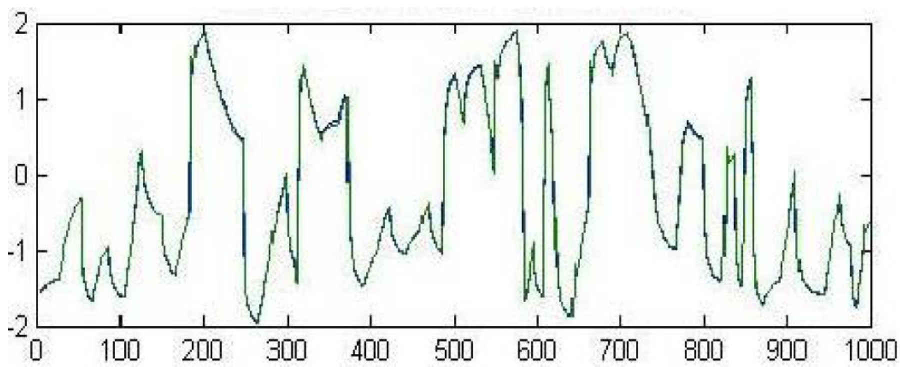


Figure 5: Validation MSE = 0.0144

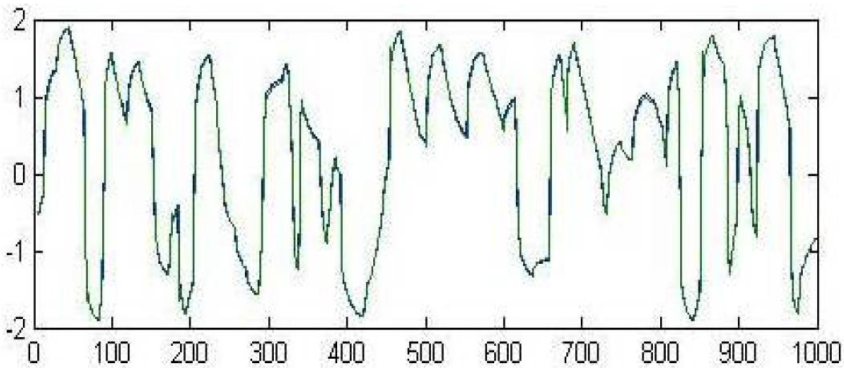
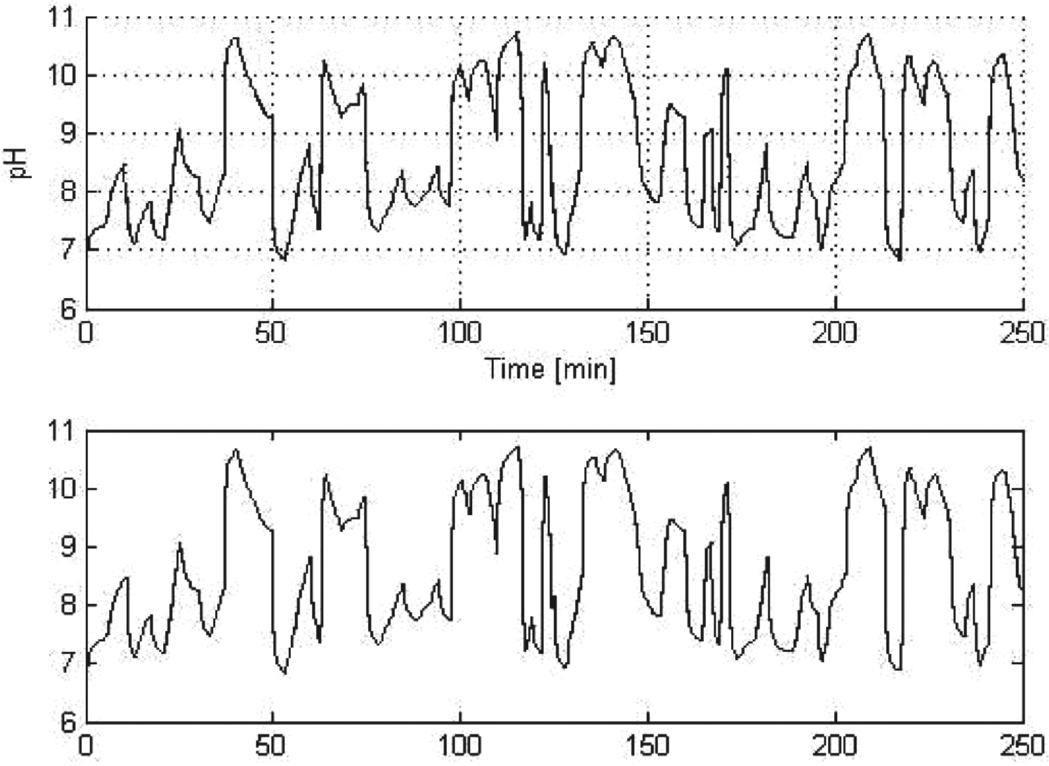


Figure 6: Fuzzy Modeling Output



training of the network, and the trained model is shown in Figures 4, 5 and 6 shows the different type of system identification methods are analyzed and suitable method were underlined to the process Neural network model.

CONCLUSION

To overcome the difficulty of neutralized pH value stable control for the clarifying process in the sugar refineries. Neural controller used to control neutralized pH value is designed in this paper. In this method, with model network, is able to guide the controller to learn and train better with partial prior knowledge of the controlled system known. Neural combining the concepts of reinforcement learning is used to optimize and control the neutralized pH value for sugar clarifying section. The research indicates that this method has good control results and abilities for anti-disturbances. This will build a good foundation. The research indicates that this method has good control results and abilities for anti-disturbances. This will build a good foundation for implementation in real-time control in the future.

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