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Verification of Neighborhood Model for Diffusion Stage of Sugar Production

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Abstract

The article assesses the adequacy of the linear relational neighborhood model of the stage of diffusion of sugar production, obtained by parametric identification on the basis of a monthly sampling of production data from the JSC "Aurora", the Borinsky sugar factory, with a time interval of 10 minutes. Observed daily changes in the coefficients of the linear model and their significance levels are explained by fluctuations in the quality of raw materials and correspond to the production technology. The conclusion is made about the local adequacy of the linear approximation for moderate changes in the quality of raw materials and the need for a transition to a piecewise linear adaptive model with a neural network switch of regimes. Training of such a switch is proposed to be based on the clustering of the whole data array (per season) in order to identify several regimes corresponding to raw materials of different quality.

Keywords: relational neighborhood system, parametric identification.

Relational neighborhood model of the stage of diffusion of sugar production.

In [1] - [3], a relational neighborhood model was proposed for the diffusion stage of sugar production. Figures 1 and 2 show the technological block diagram of obtaining diffusion juice and the corresponding neighborhood structure.

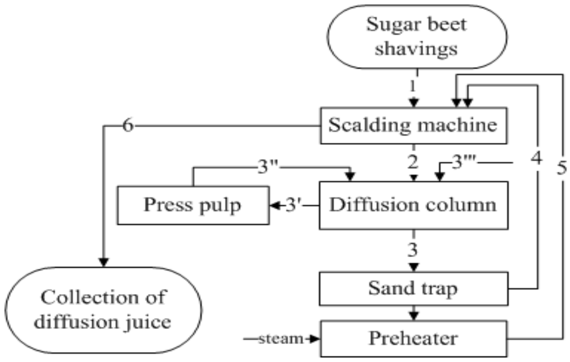

Figure 1. Technological block-diagram for diffusion stage

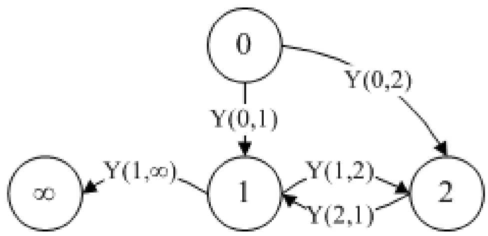

Figure 2: The neighborhood structure of the diffusion stage

The relational neighborhood system has the form

$$\begin{cases} Y(1,2) = F_{1,2}(U(1), Y(0,1), Y(2,1)) \\ Y(1,\infty) = F_{1,\infty}(U(1), Y(0,1), Y(2,1)) \\ Y(2,1) = F_{2,1}(U(2), Y(0,2), Y(1,2)) \end{cases} \quad (1).$$

For an explanation of all the notation see [1].

Verification of the linear relational neighborhood model.

In articles [1] - [3], the results of parametric identification for linear version of the model (1) were presented. The identification was based on the production data sampling from JSC AIA (Agroindustrial Association) «Avrora» Borinsky sugar plant for 14.09.2016 from 00:00 to 23:50 p.m. with a time interval of 10 minutes. The calculations were carried out in the package Statistica 10. The obtained dependences were described in terms of the technology of the sugar process. We estimate the adequacy of the linear relational neighborhood model on the basis of the analysis of the results of the daily parametric identification of the yield from the scalding machine on the diffusion column (the first equation of the system) according to data for the period from 05.11.2016 to 26.11.2016. The analysis of the samples showed the presence of a small number of fluctuations of the data, significantly exceeding the limits of the normal approximation of the samples. These data were smoothed out by replacing them with their arithmetic mean values at time instants $t-1$ and $t+1$. Below in Fig. 2, diagrams of correlation coefficients of the temperature and flow rate of the juice-grinding mixture with all variables entering the equation for leaving the scalding machine for the diffusion column are given, for the period from 5.11.2016 to 10.11.2016 (six days, the coefficients are carried out for each day). On other days, there was a similar picture.

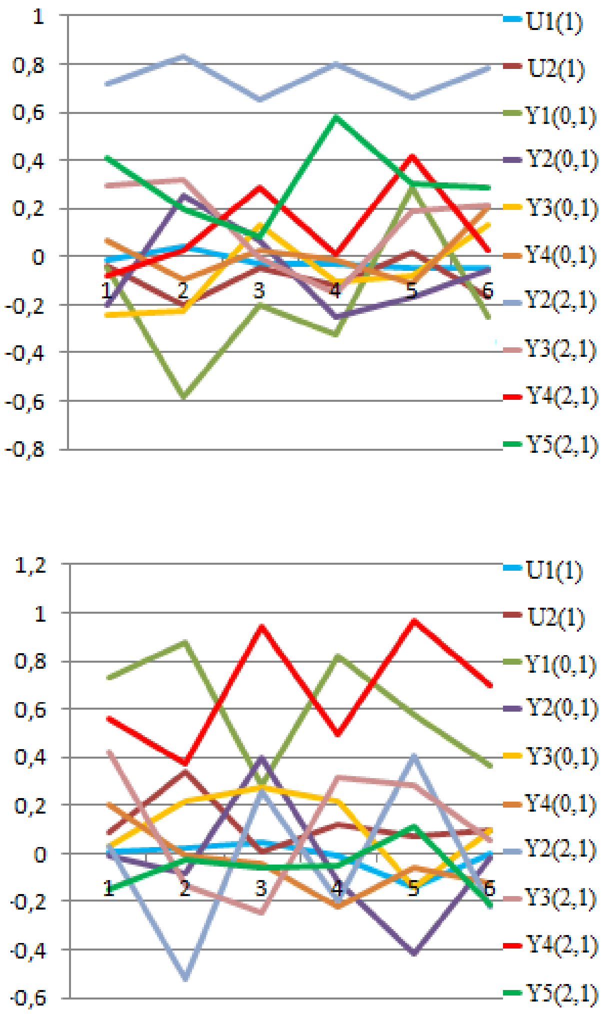

Figure 2: Oscillation of correlation coefficients over 6 days

Here $U_1(1)$ - level in the scalding machine shaft before the sieve, %; $U_2(1)$ - level in the scalding machine mixer before the sieve, %; $Y_1(0,1)$ - shavings consumption, m3/h; $Y_2(0,1)$ - length 100 g shavings, m, $Y_3(0,1)$ - % of defective shavings; $Y_4(0,1)$ - shavings sugar content, %; $Y_2(2,1)$ - the temperature at the bottom of column, $^{\circ}C$; $Y_3(2,1)$ - consumption of diffusion juice into the scalding machine shaft, m3/h; $Y_4(2,1)$ - consumption of diffusion juice into the scalding machine mixer m3/h; $Y_5(2,1)$ - the temperature of the juice in the scalding machine mixer after the heaters, $^{\circ}C$.

Oscillations of the correlation coefficients lead to appreciable changes in the model coefficients and, moreover, to the instability of the set of significant predictors. The reason for this instability is a change in the quality of raw materials, which leads to a fluctuation of the real observable values of the technological parameters relative to the nominal ones.

Examples.

1. The production received partly decayed beet, technological indicators of the quality of beet shavings which lie within the norm. Due to the fact that the beet shavings are not sufficiently elastic, to prevent its overheating, a diffusion juice with a temperature below the technological index is supplied to the scalding machine shaft.
2. When the frosted beet enters the processing, it is necessary to increase the pH of the feed water.
3. On the evaporator (this is the next production stage, in Scheme 1 it is absent), the content of dry soluble substances in the sugar syrup is lower than the technological index. As a consequence, the evaporation process increased in time. Consequently, the point in the diffusion juice container became higher, the productivity decreased.

Analysis of the results of the daily parametric identification showed the presence of the following dependencies, sufficiently stable on the basis of significance.

For the temperature of the juice-shavings mixture $Y_1(1,2)$*:*

1. The temperature of the juice-based mixture $Y_1(1,2)$ depends on the temperature at the bottom of the column $Y_2(2,1)$ and the temperature of the juice $Y_5(2,1)$ in the scalding machine mixer after the preheater (coefficient of multiple correlation $R = 0,69 \div 0.86$);
2. The temperature of the juice-shavings mixture depends $Y_1(1,2)$ от temperature at the bottom of the column $Y_2(2,1)$ (coefficient of multiple correlation $R = 0,52 \div 0.87$).

From the point of view of the sugar refining technology, for the diffusion process, the beet shavings must be heated to the temperature of denaturation of the protoplasm of the shavings cells. To do this, the beet shavings in the scalding machine are heat treated stepwise with two streams of diffusion juice to obtain a juice-shaving mixture: first it heats up to 34-35 °C diffusion juice with a temperature equal to the temperature of the juice at the outlet of the diffusion column (70-72 °C), and then finally to 72-74 °C – by juice heated in the heater to 76 °C. As a result, the temperature of the juice-shavings mixture depends on the temperature of the heat carriers of these two streams, namely, the temperature of the bottom of the column and the temperature of the juice after the preheater. However, depending on the quality of the raw material (beet), it is also possible to heat the juice-shavings mixture only with the diffusion juice supplied from the outlet of the diffusion column.

For the consumption of the juice-shavings mixture $Y_2(1,2)$:

1. The consumption of the juice-shavings mixture $Y_2(1,2)$ depends on the shavings consumption $Y_1(0,1)$, consumption of diffusion juice into the shaft $Y_3(2,1)$ and of scalding machine mixer $Y_4(2,1)$ (coefficient of multiple correlation $R = 0,90 \div 0.98$);

2. The consumption of the juice-shavings mixture $Y_2(1,2)$ depends on the quality of the loaded beet shavings $Y(0,1)$, shavings consumption $Y_1(0,1)$ and the consumption of diffusion juice into the shaft $Y_3(2,1)$ and the scalding machine mixer $Y_4(2,1)$ (coefficient of multiple correlation of a model with three predictors $R = 0,90 \div 0.98$).

According to the sugar refining technology, the juice-shavings mixture is obtained by mixing the beet shavings heated by diffusion juice in the shaft with a diffusion juice fed into the scalding machine mixer. In order to efficiently proceed with the diffusion process, it is necessary to keep the temperature in the lower part of the column at a level of 70-72 ° C, with the proper expenditure of the diffusion juice for scalding. But it is also necessary to take into account the quality of the beet shavings to be loaded.

The results of the parametric identification of the equation for leaving the scalding on a diffusion column based on the averaged data for the period from 05.11.2016 to 26.11.2016 :

$$Y_1(1,2) = 0.994 * Y_2(2,1) - 2.842, R = 0.99;$$

$$Y_2(1,2) = 0.540 * Y_1(0,1) + 0.940 * Y_4(2,1) + 1.905, R = 0.99.$$

CONCLUSIONS

When constructing linear regression models from data related both to different days and to different time intervals over a single day, changes in regression coefficients and sets of significant predictors of the regression equation. This confirms our a priori assumption that a universal linear model is most likely impossible and a nonlinear relational neighborhood model is required to build a complete management system. At the same time, all the obtained daily linear regression dependencies correspond to the sugar refining technology, and the changes in coefficients and predictors are fairly well explained by fluctuations in the quality of raw materials. Therefore, the introduction of analytic non-linearity (for example, bilinearity) into the model does not make sense. More promising is an adaptive piecewise linear model. It is necessary to cluster all data files (per season) in order to identify several modes corresponding to raw materials of different quality. For each mode, it should be indicated the nominal values of the controlled parameters and the corresponding (local) linear relational model. The additional unit of the general model must switch from one nominal mode to another after analyzing the parameters of the raw material. This block, presumably, can be implemented by a neural network. Switching from one mode to another should be accompanied by switching to a pre-built linear model corresponding to this mode. Then there are two possibilities for maintaining the system near the specified nominal mode (corresponding to the raw material of approximately constant quality). First, for management, one can use the selected local linear model without any changes to it. Secondly, we can consider this model as a preliminary model and implement adaptive control, that is, to recalculate the coefficients of the model. Such a recalculation can be done permanently, either with a selected interval of time, or with the appearance of a marked instability of control. In this mode, moderate changes in the coefficients of the model will occur.

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