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Cover Page Footnote

Erratum
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THE PROBLEM OF PHASIFICATION OF THE PARAMETERS OF THE STORAGE PROCESS OF A SPORTSHEAD OIL RAW MATERIAL WHEN BUILDING A FUZZY REGULATOR

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Abstract: the article proposes an automated intelligent process control system for the storage of perishable oilseed raw materials based on phase-control. To solve the problem of phasing the process parameters, the modified Saaty method is used. In order to optimize the description, the obtained membership functions were approximated in the Maple symbolic mathematics package.

Keywords: phase-control, pacification, linguistic variables, membership function, rule base, Saaty method, fuzzy sets, oilseeds.

When automating the management of processes, the storage of perishable oil-bearing raw materials is not enough to ensure the stabilization of technological regimes using PID-regulators. The quality and performance of such processes substantially depend on a combination of environmental parameters, which forces the process technician to constantly adjust the controller settings as the external conditions change, guided by his own professional experience. An automated intelligent control system that manages the processes of storing perishable oilseed raw materials using the practical experience and knowledge of the person (technologist) can be built using the principles of phase-control (fuzzy control) [1].

Consider the issue in relation to the process of storing perishable oilseeds in storage. Practical experience showed that the results of the technological process, first of all, depend on the temperature of the air in the storage, the moisture content of the raw materials and air, and the concentration of carbon dioxide [2]. The intensity of the storage process and the quality of the stored products essentially depend on the combination of the listed process parameters. However, the optimal combination of parameters, ensuring maximum performance and quality, and minimum process costs, do not remain constant and significantly depend on the process conditions: time of year, quality of technological materials, etc. For example, carbon dioxide content in the storage air is controlled by its ventilation. However, the efficiency of the ventilation process and the required energy consumption for air preparation are significantly different in the summer and winter periods.
The advantage of “$T_{C1}$ °C” over “$T_{I5}$ °C” is 6;
The advantage of “$T_{C1}$ °C” over “$T_{I3}$ °C” is 3;
The advantage of “$T_{C1}$ °C” over “$T_{I2}$ °C” is 1;
The advantage of “$T_{C1}$ °C” over “$T_{II}$ °C” is 1.
The results of the comparisons are presented in the form of a matrix (1), where $a_{ij}$ is the level of the advantage of the element $u_i$ over $u_j$ ($i, j = 1, n$).

\[
\begin{array}{cccccc}
T_{I5} & T_{I4} & T_{I3} & T_{I2} & T_{II} & T_{C1} \\
1 & 1 & 1 & 1 & 1 & \\
T_{I4} & 1 & 1 & 1 & 1 & \\
T_{I3} & 1 & 1 & 1 & 1 & \\
T_{I2} & 1 & 1 & 1 & 1 & \\
T_{II} & 1 & 1 & 1 & 1 & \\
T_{C1} & 9 & 6 & 3 & 1 & 1 & 1 \\
\end{array}
\]

The matrix has the following properties: it is diagonal, it is inversely symmetric, it is transitive. These properties allow you to define all other elements of the comparison matrix using the formula (2):

\[ a_{ij} = a_{kj} / a_{ki} \text{, where } i, k, j = 1, \quad (2) \]

For the term “sn”, we define the kernel of a fuzzy set, described by the membership function equal to $T_{C1}$ °C (center of the temperature interval $\Delta T_i$), and the boundaries of the fuzzy set are compatible with the kernels of fuzzy sets of neighboring terms. The function of belonging to the term “sn” will have a left shoulder and a right shoulder. Select 7 equidistant points ($T_{I1}$, $T_{I2}$, $T_{I3}$, $T_{I4}$, $T_{I5}$) on the left shoulder, including the core, and compare the value of the core ($T_{C1}$ °C) with the selected points (except for the value of the core of the next term). When comparing, we use the rating scale [9,10]: 1 - there is no advantage; 3 - weak advantage; 5 - a significant advantage; 7 is a clear advantage; 9 is an absolute advantage; 2, 4, 6, 8 - intermediate estimates.

Taking into account the opinion of the expert, the following estimates were obtained: The advantage of “$T_{C1}$ °C” over “$T_{I5}$ °C” is 9;

The value of the membership function for the left shoulder of the term “sn” is 1.

AFTER...

Let's analyze all the elements of the matrix of pairwise comparisons (3), we find the values of the membership function by the following formula (4):

\[ \mu(u_i) = \frac{1}{a_{i1}+a_{i2}+\ldots+a_{ni}}, \quad (4) \]

where $n = 6$; $u_i$ - the $i$-th element of pairwise comparison (column); $a_{ii}$ is the first value of the pairwise comparison of the $i$-th element; $a_{ni}$ is the $n$-th value of the pairwise comparison of the $i$-th element. After rationing the calculated values by dividing them by the largest value, we obtain (Table 2).
Using the piecewise linear approximation of the MF in the intervals between the calculated reference points, we obtain analytical expressions for the corresponding parts of the membership function for the left shoulder of the term “sn” (5):

\[
\begin{align*}
T \leq T_{\text{min}}; & \quad \mu_{\text{sn}}(T) = 0; \\
T_{\text{min}} < T \leq T_{15}; & \quad \mu_{\text{sn}}(T) = 0.6877T - 8.25; \\
T_{15} < T \leq T_{16}; & \quad \mu_{\text{sn}}(T) = 0.2947T - 3.466; \\
T_{16} < T \leq T_{17}; & \quad \mu_{\text{sn}}(T) = T - 12.17; \\
T_{17} < T \leq T_{18}; & \quad \mu_{\text{sn}}(T) = 4.1877T - 52.013; \\
T_{18} < T \leq T_{19}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{19} < T \leq T_{21}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{21} < T \leq T_{23}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{23} < T \leq T_{25}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{25} < T \leq T_{27}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{27} < T \leq T_{29}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{29} < T \leq T_{31}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{31} < T \leq T_{33}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{33} < T \leq T_{35}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{35} < T \leq T_{37}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{37} < T \leq T_{39}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{39} < T \leq T_{41}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{41} < T \leq T_{43}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{43} < T \leq T_{45}; & \quad \mu_{\text{sn}}(T) = 1;
\end{align*}
\]

(5)

where \(T\) is the air temperature in the storage; msn \((T)\) - membership function of the term “sn”. To build the right shoulder use the same algorithm.

After combining the descriptions of the left and right shoulders of the MF, we obtain a complete description of the MF for the term “sn”

\[
\begin{align*}
T \leq T_{\text{min}}; & \quad \mu_{\text{sn}}(T) = 0; \\
T_{\text{min}} < T \leq T_{15}; & \quad \mu_{\text{sn}}(T) = 0.6877T - 8.25; \\
T_{15} < T \leq T_{16}; & \quad \mu_{\text{sn}}(T) = 0.2947T - 3.466; \\
T_{16} < T \leq T_{17}; & \quad \mu_{\text{sn}}(T) = T - 12.17; \\
T_{17} < T \leq T_{18}; & \quad \mu_{\text{sn}}(T) = 4.1877T - 52.013; \\
T_{18} < T \leq T_{19}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{19} < T \leq T_{21}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{21} < T \leq T_{23}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{23} < T \leq T_{25}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{25} < T \leq T_{27}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{27} < T \leq T_{29}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{29} < T \leq T_{31}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{31} < T \leq T_{33}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{33} < T \leq T_{35}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{35} < T \leq T_{37}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{37} < T \leq T_{39}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{39} < T \leq T_{41}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{41} < T \leq T_{43}; & \quad \mu_{\text{sn}}(T) = 1; \\
T_{43} < T \leq T_{45}; & \quad \mu_{\text{sn}}(T) = 1; \\
T > T_{45}; & \quad \mu_{\text{sn}}(T) = 0;
\end{align*}
\]

(6)

where \(T\) is the air temperature in the storage; msn \((T)\) - membership function of the term “sn”. To simplify the description of the MF, we perform an approximation to the piecewise linear characteristic by the Lagrange polynomial. The approximation used the Maple symbolic mathematics package, for which the following procedure is described:

\[
lagr := \text{proc (Data::(list(list)))} \\
\text{local L, s, s1, Lg, x;} \\
\text{L := 0;}
\]

for \(s\) in Data do
if \(s[1][1] < s[1]\) then
\[
Lg := \text{Lg}*(x-s[1])/(s[1][1]-s[1]);
\]
end if;
end do;
L := L+s[1][2]*Lg;
end proc;
As a result of the approximation for the left shoulder of the MF, the description is obtained in the following form (7):

\[
\begin{align*}
T \leq 9; & \quad \mu_{\text{sn}}(T) = 0; \\
9 < T \leq 11; & \quad \mu_{\text{sn}}(T) = a_{sn-l} + a_{sn-l}T + \\
& + \sum_{n=2}^{\text{n}} a_{sn-l}^n (T - \Delta T_{sn})^n; \\
T > 13; & \quad \mu_{\text{sn}}(T) = 0;
\end{align*}
\]

(7)

where \(T\) is the air temperature in the storage; \(\Delta T_{sn} = 11\); msn \((T)\) - membership function of the term "sn"; \(a_{sn-l} = -2,52\); \(a_{sn-l}^0 = 0,27\); \(a_{sn-l}^\text{n} = 3,177\); \(a_{sn-l}^3 = 20,833\); \(a_{sn-l}^4 = 29,947\); \(a_{sn-l}^5 = 13,02\);
Together with the right shoulder, the description of the MF sn will take the form (8):

\[
\begin{align*}
T \leq 9; & \quad \mu_{\text{sn}}(T) = 0; \\
9 < T \leq 11; & \quad \mu_{\text{sn}}(T) = a_{sn-l} + a_{sn-l}T + \\
& + \sum_{n=2}^{\text{n}} a_{sn-l}^n (T - \Delta T_{sn})^n; \\
11 < T \leq 11; & \quad \mu_{\text{sn}}(T) = a_{sn-r} + a_{sn-r}T + \\
& + \sum_{n=2}^{\text{n}} a_{sn-r}^n (T - \Delta T_{sn})^n; \\
T > 11; & \quad \mu_{\text{sn}}(T) = 0;
\end{align*}
\]
where $T$ is the air temperature in the storage; $\Delta T_{sn} = 11$; $msn\,(T)$ - the membership function of the term "sn";

$a_{sn-l} = -2.52; \quad a_{sn-t} = 0.27; \quad a_{sn-l}^2 = 3.177;$

$a_{sn-t}=20.833; \quad a_{sn-l}^4 = 29.947; \quad a_{sn-l}^5 =13.02; \quad a_{sn-r}=4.52; \quad a_{sn-r}^2 =0.27; \quad a_{sn-r}^4 =3.177;$

$a_{sn-r}^5=20.833; \quad a_{sn-r}^4=29.947; \quad a_{sn-r}^5=13.02;$

The graphs for the initial version of the MF and the approximated dependence are presented in (Fig. 2). The approximate dependence is more consistent with the experience of the technologist, since it eliminates the horizontal part of the characteristic in the vicinity of the core.

![Fig. 3. The membership functions of the value “Temperature in the storage” to the terms of the linguistic variable “Temperature mode”](image)

At the same time, the nature of the change in the remaining intervals is preserved in accordance with the original schedule of the membership function. Using the described approach, the membership functions for the temperature in the storage are defined for all terms of the linguistic variable “Temperature mode”, which allows phasing for this parameter of the storage process. Graphs of membership functions are shown in Fig. 3.

Thus, an intelligent process control system has been proposed for storing perishable oilseeds based on fuzzy logic, which allows you to use the accumulated experience of the plant technologist to optimize the operation of the complex in order to increase productivity, product quality and reduce costs. The question of the phasification of process parameters on the example of the parameter "temperature" using the modified Saaty method is considered. A new form of the membership function and its approximation is obtained.

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