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Evaluation of complex technical objects models by linguistic variables

A new approach of different complex technical objects models connection based on fuzzy logics is proposed. The result of evaluation of complex technical objects models by linguistic variables is provided.

At the stage of creation of complex technical objects (CTO) components in the conditions of uncertainty, it is difficult to estimate influence between models. [1] In this regard, it is advisable to use linguistic variables to evaluate CTO models. [2]

The problem of constructing the dependence of parameters is considered: geometrical model: $m_{Gi} - p_{Gi}$; strength model: $m_{Si} - p_{Si}$; weight model: $m_{Wi} - p_{Wi}$ CTO component. [3]

The paper considers the most frequently used Mamdani model and contains fuzzy values in the consequences of the rules of logical inference. Fig. 1 shows the membership functions of the terms in accordance with the economically justified values of the weight model constraints and the values of the strength model on the example of the aircraft ramp.

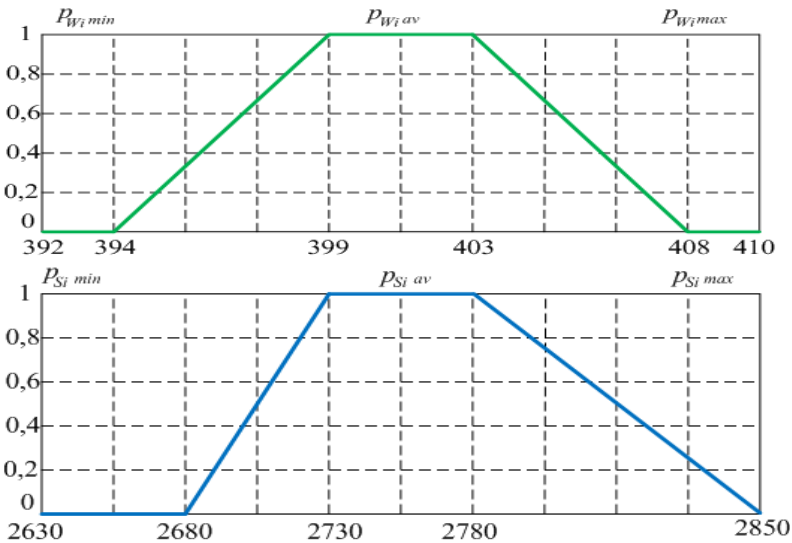

Fig. 1. Terms of the weight model (variable p_{Wi} ,kg) and strength models (variable p_{Si}, kg/m^3) on the example of the aircraft ramp

The next step in building a fuzzy model is to create a database of rules:

1). IF pWi IS PWimin AND pSi IS PSimin THEN pGi IS PGimin
2). IF pWi IS PWimin AND pSi IS PSiav THEN pGi IS PGiav
3). IF pWi IS PWimin AND pSi IS PSimax THEN pGi IS PGiav
4). IF pWi IS PWiav AND pSi IS PSimin THEN pGi IS PGiav
5). IF pWi IS PWiav AND pSi IS PSiav THEN pGi IS PGiav
6). IF pWi IS PWiav AND pSi IS PSimax THEN pGi IS PGimax
7). IF pWi IS PWimax AND pSi IS PSimin THEN pGi IS PGiav
8). IF pWi IS PWimax AND pSi IS PSiav THEN pGi IS PGimax
9). IF pWi IS PWimax AND pSi IS PSimax THEN pGi IS PGimax

In the Mamdani model, each rule has a degree of execution ω_i, which is calculated as follows:

$$\omega_i (p_1 \ldots p_{n_p}) = \bigcap_{j=1}^{n} \mu_{j,i}(p_j), \; i=1 \ldots n_R,$$

where **I** – fuzzy conjunction operation, which corresponds to the operator "AND" in the rules, which can be specified using different t-norms, such as: minimum, product, etc.; n_p – number of inputs (in this case $n_p = 2$); $\mu_{j,i}(p_j)$ – membership function at the j-th entrance in the antecedent of the i-th rule; n_R is the number of rules (in this case $n_R = 9$).

After calculating the degree of rule execution, with the help of implication (in Mamdani systems, the minimum operation is usually used), fuzzy values of rule rules are calculated. Then, using the aggregation operation (Mamdani systems usually use the maximum operation), fuzzy output values with the membership function are calculated $\mu_{P_{res}}(p_G)$ in accordance with the expression:

$$\mu_{p_{res}}(p_G) = \bigcup_{i=1}^{n_R} (\omega(p_1 \ldots p_{n_p}) \bigcap \mu_{p_{Gi}}(p_G)),$$

where **U** − the aggregation operation, which corresponds to the union of fuzzy rules according to ELSE, in the Mamdani system is equivalent to disjunction; **I** − implication operation (in the Mamdani system is equivalent to a conjunction); $\mu_{P_{Gi}}(p_G)$ − the membership function of the consequent of the *i-th* rule. When using a maximum as an aggregation operator and a minimum as an implication operator, the procedure for obtaining a fuzzy output value is called *a max-min composition*.

When the rule inputs are processed by the algorithm described above and a fuzzy output is obtained $\mu_{P_{res}}(p_G)$, it is necessary to find the corresponding clear value by means of defasification p_G^*.

The main methods of dephasing are: the method of center of gravity, center of sums or average maximum.

Defasified test by the method of the center of gravity is determined by:

$$p_G^* = \frac{\sum_{i=1}^{N_{p_G}} p_{G_i} \mu_{p_{G_{res}}}(p_{Gi})}{\sum_{i=1}^{N_{p_G}} \mu_{p_{G_{res}}}(p_{Gi})},$$

where summation is performed on discrete values p_{Gi} output area divided by N_{p_G} points.

According to the method of the center of sums, the membership function of the output is built by summing (aggregation by the sum, not combining by the maximum) of the outputs of each of the rules that worked:

$$p_G^* = \frac{\sum_{i=1}^{N_{p_G}} p_{G_i} \sum_{k=1}^{n} \mu_{0,k}(p_{Gi})}{\sum_{i=1}^{N_{p_G}} \sum_{k=1}^{n} \mu_{0,k}(p_{Gi})}.$$

In the method of defasification it is necessary to take a clear maximum value of the degree of membership of the function $\mu_{P_{res}}(p_G)$. If there are several elements of the definition area with the maximum value of the degree of affiliation, the average value of the maximum is selected:

$$p_G^* = \sum_{m=1}^{M} \frac{p_{Gm}}{M}.$$

The study implemented a fuzzy Mamdani result using the Java language for the problem of constructing the dependence of the parameters of the weight model: $m_{Wi} - p_{Wi}$ from the parameters of the geometric model: $m_{Gi} - p_{Gi}$ and strength model parameters: $m_{Si} - p_{Si}$ CTO component, which reduces the time of creation of CTO by managing the parameters of CTO model.

References

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