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The system for prediction of security state of an enterprise in the aviation industry using semantic–frame fuzzy models of knowledge base

As a result of modeling, it was found that introduction of the prediction unit into a system allows us more accurately and objectively to consider and evaluate a whole range of indicators of the enterprise's operation. The proposed prediction system calculated approximated prospective value of the indicator of the state of technical and technological potential of an enterprise in time, which greatly affects probability of bankruptcy of an enterprise. It is appropriate to use the prediction system for complex processes with fuzzy logic, when there is no simple mathematical model and expert knowledge can be formulated without fuzzy logic only in linguistic form. This proves that the proposed system can be used for prediction of all other potential of an enterprise that also impact probability of bankruptcy of an enterprise.

Description of the scheme of the system for prediction potential of enterprises in the aviation industry

The use of semantic models enables accumulation of knowledge in the base and implementation of automatic construction of semantic networks directly from classes of indicators. The characteristic feature of semantic models of economic security of an enterprise (EcSE) system is an integrated description of procedure and static semantics, permissible procedures of operations on the objects that are determined in conjunction with determining of the data structures of a network.

The structure of the proposed system includes the object-oriented semantic-frame network (SFN) of presentation of knowledge about the state of technical and technological potential of an enterprise. The system provides precise current values of performance indicators of an enterprise, properties, and permissible limits of these properties. The system includes units of classes of indicators, and bases of the facts of separate instances of classes [1, 2, 3].

SFN of potentials can intersect. That is, the elements of one SFN on the example of technical and technological potential (TTP) can also be the elements of another SFN. Classes of indicators of SFN of TTP are shown in Table 1 [2].

Graphical view of the structural SFN of TTP of an enterprise consists of sequentially and in parallel connected units: classes, slots, the facts of individual instances of classes and is shown in Fig. 2 and developed by the Protégé system (Stanford University), which is one of the most professional systems of working with semantic-frame models (languages for recording semantic models of RDF, RDFS) [4, 5, 6]. A semantic model is used in order to display all the richness of attributes and relationships of the elements of the system that are modeled. Logical and mathematical calculations that allow finding the optimum solution are made on this model. As a rule, such modeling is sliding: the model is constantly updated due to arrival of new information about the state of the system.

Table 1

Indicators of semantic-frame network of technical and technological potential of an enterprise in the aviation industry

Indicators of TTP (Classes of SFN)	Properties-slots of TTP (calculation of clear conclusion of SFN in machine)
$c_{1,1}$ – capital productivity of fixed assets $c_{1,2}$ – average annual cost of fixed assets, UAH, enterprise, UAH. $z_{3,10}$ – total receipts (Source →SFN of marketing potential), UAH.	$c_{1,1}=z_{3,10}/c_{1,2}$
$c_{1,3}$ – capital-labor ratio, UAH; $c_{1,4}$ – average number of employees by list, people	$c_{1,3}=c_{1,2}/c_{1,4}$
$c_{1,5}$ – coefficient of retirement of fixed assets; $c_{1,6}$ – cost of fixed assets, retired within reporting period, UAH; $c_{1,7}$ – cost of fixed assets at the beginning of reporting period, UAH.	$c_{1,5}=c_{1,6}/c_{1,7}$
$c_{1,8}$ – coefficient of capital renewal; $c_{1,9}$ – cost of acquired fixed assets within reporting period, UAH.	$c_{1,8}=c_{1,9}/c_{1,7}$
$c_{1,10}$ – coefficient of wear and tear of fixed assets; $c_{1,11}$ – coefficient of wear and tear of fixed assets for correspondent period, UAH.	$c_{1,10}=c_{1,11}/c_{1,7}$
$c_{1,12}$ – material consumption; $c_{1,13}$ – material costs, UAH. $z_{3,10}$ – total receipts, UAH.	$c_{1,12}=c_{1,13}/z_{3,10}$
$c_{1,14}$ – coefficient of profitable use of materials; $c_{1,15}$– cost of wastes by prices of fully-fledged raw materials, UAH.	$c_{1,14}=(c_{1,13}-c_{1,15})/c_{1,13}$
$c_{1,16}$ – coefficient of faulty production; $c_{1,17}$ – costs of faulty production by cost value of sold production, UAH. $q_{1,10}$ – full cost value of sold production, UAH. (Source – SFN of financial potential).	$c_{1,16}=c_{1,17}/q_{1,10}$

The system of prediction of security state of an enterprise with the use of semantic-frame fuzzy models of knowledge base was proposed. This system can be used by small and medium enterprises for solving specific tasks, it does not require significant investments and can be adapted in the form of an application to ERP systems.

The block-diagram of security state of an enterprise (SSE) prediction consists of sequentially and in parallel connected structural elements-units (Fig. 1):

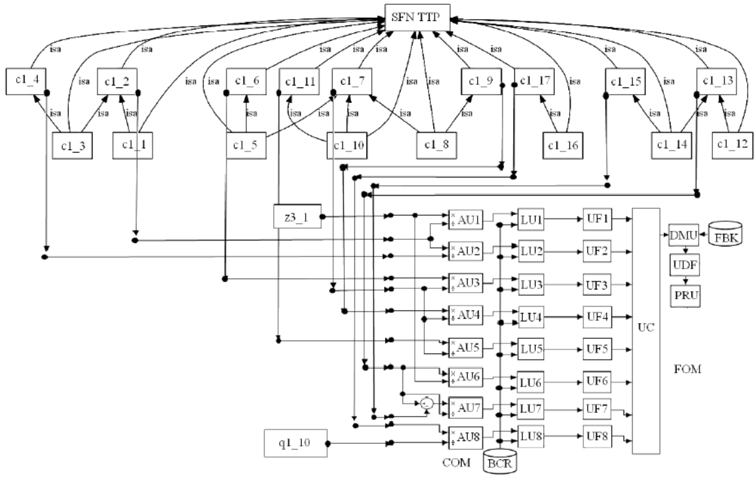

Fig. 1. Block-diagram of prediction of security state of technical and technological potential of an enterprise

Unit c1_j (j=1,...,16) is the unit of frames of classes of TTP indicators, which presents clear current values of TTP indicators of operation of an enterprise and properties of SFN classes.

Unit fact_t_t_p is the fact base (FB) of separate incidents of classes, structures by SFN.

Unit z3_10 is the indicator "total receipts" (Source – SFN of marketing potential).

Unit q1_10 is the indicator "full cost value of sold produce" (Source – SFN of financial potential).

Units AU1–AU8 are the arithmetic units of clear output machines (COM), for calculation of clear rules of BCR of COM of SFN.

Units LU1–LU8 are the logic units of the clear output machine for calculation of permissible restrictions of BCR of COM of SFN

Unit BCR is the base of clear rules of a clear output machine

Units UF1–UF8 are the units of fuzzification of fuzziness (introduction of fuzziness), which transforms numerical input values into the degree of correspondence to linguistic variable by the rules. Degrees of truth for prerequisites of each rule: $\mu_{jp}(x_i^*)$, i=1, 2,..., n; j=1, 2,..., m; p=1, 2,..., k_j.

Using fuzzification, clear value is in conformity with the degree of its membership in fuzzy sets, the determined membership functions of fuzzy sets are used in fuzzy rules.

Unit UC is the composition unit. All fuzzy subsets, assigned to each variable – an output indicator, are combined to form a single fuzzy subset for all output variables. At a similar combination, operations max (maximum) or sum

(sum) are used. At composition of maximum, combined output of a fuzzy subset is constructed as point-by-point maximum of all fuzzy subsets. At composition of sum, combined output of a fuzzy subset is formed as point-by-point sum of all fuzzy subsets, assigned to output variable by rules of inference.

Unit FBK is the fuzzy base of knowledge about the impact of indicators $x=\{x_1, x_2,..., x_n\}$ on the value of the parameter, which is a set of logic expressions like:

$$\bigcup_{p=1}^{k_j}\left[w_{jp}\bigcap_{i=1}^{n}\left(x_i = a_i^{jp}\right)\right] \rightarrow y = d_j, \quad j = 1, 2, ..., m,$$

where a_i^{jp} is the fuzzy term, which assesses variable x_i in the line with number jp (p=1, 2,..., k_j); k_j is the number of lines–conjunctions, in which output is assessed by fuzzy term d_j, j=1, 2,..., m; m is the number of terms, used for linguistic assessment of output parameter y, w_{jp} is the weight of the p-th line of conjunctions of the j-th rule of knowledge base.

Current FBK of SFN consists of a set of fuzzy rules, membership functions of fuzzy sets, sets of input and output linguistic variables. SFN in the Protege is constructed as a tree and is made up of classes and relations between them [20].

Thus, a set of arcs of homogenous informational SFN structure determines classifying relationship, similar to *ako*-relation and i*sa*-relation. FBK of SFN was reduced and implemented by plug-in JESS for Protégé [21, 22]:

1) (c1_1==mf1) or (c1_3==mf1) or (c1_5==mf1) or (c1_8==mf1) or (c1_10==mf3) or (c1_12==mf1) or (c1_14==mf1) or (c1_16==mf1) => (TT_ potential=Low_level)

2) (c1_1==mf3) or (c1_3==mf3) or (c1_5==mf3) or (c1_8==mf3) or (c1_10==mf1) or (c1_12==mf3) or (c1_14==mf3) or (c1_16==mf3) => (TT_ potential=High_level)

3) (c1_1==mf2) & (c1_3==mf2) & (c1_5==mf2) & (c1_8==mf2) & (c1_10==mf2) & (c1_12==mf2) & (c1_14==mf2) & (c1_16==mf2) => (TT_ potential=Middle_level)

4) (c1_1==mf1) or (c1_3==mf1) or (c1_5==mf1) or (c1_8==mf1) or (c1_10==mf3) or (c1_12==mf1) or (c1_14==mf1) or (c1_16==mf1) => (TT_ potential= Middle_level_50)

5) (c1_1==mf3) & (c1_3==mf3) & (c1_5==mf3) & (c1_8==mf3) & (c1_10==mf1) & (c1_12==mf3) & (c1_14==mf3) & (c1_16==mf3) => (TT_ potential=High_level_50)

6) (c1_1==mf1) & (c1_3==mf1) & (c1_5==mf1) & (c1_8==mf1) & (c1_10==mf3) & (c1_12==mf1) & (c1_14==mf1) & (c1_16==mf1) => (TT_ potential= Middle_level_50)

Membership functions can be assigned in the form of a list with explicit enumeration of all elements and corresponding values of membership function or analytically as formulas.

Indicators were separated for TTP, and for each of them polar values $\mu_A(x)\in[0, 1]$, corresponding to values of membership function 0 or 100, were determined, and vector membership function $\{\mu_A(x_1), \mu_A(x_2),..., \mu_A(x_n)\}$ was stated.

The type of membership function of SSE in a considerable degree determines properties of a fuzzy system of a fuzzy output machine (FOM).

Unit DMU is the decision-making unit that performs output operations based on existing fuzzy rules of NBZ of SFN.

Calculated value of truth for the prerequisites for each rule is applied to conclusions of each rule. This leads to one fuzzy subset that will be assigned to each output variable for each rule.

Then, using one of the fuzzy composition methods, we find the values of membership functions of conclusions of the right parts by each of the rules of fuzzy production. These values of membership functions are either the sought-for output result or can be used as additional terms in base of rules of considered productions.

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