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Research Article

Technology of an Aprioristic Objective Assessment of Distance Course Themes Complexity Based on Saati's Algorithm

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Abstract

In this article problems of determination the distance course theme's complexity. The structure of a distance course represents an ontotlogiya in which each element has the value of weight coefficient, communications between model elements also have weight coefficients.
For an assessment of complexity presented in distance course "Machine-dependent languages" themes it was aware to use the Saati's method of the hierarchies analysis, procedure of check of expert estimates of complexity by that was also carried out. Also the assessment of quality of the ontologic model of a distance course which is given in the results description of the carried-out work was also executed.

Keywords: theme complexity, weight coefficient, matrix of paired comparisons, T. Saati's algorithm

1. Introduction

Structurization of lecture material provides high efficiency of its perception with students. Text quantization is one of types of similar structurization. Now quantitative methods of an educational text quantization quality assessment are developed (A.A.Rybanov, 2014). Allocation of theme key elements and formation of a test tasks set for knowledge control of these elements allow to find more precisely course elements, difficult for assimilation by students, which can be modified further: simplification of elements statement style, material expansion with practical examples, etc. At the same time there is a problem of exposure of the total assessment considering complexity that a training course.

The knowledge of an aprioristic assessment of distance course theme's assimilation complexity, that is the assessment preceding studying of a theme by student and predicting statistical difficulty, is necessary for the teacher, on the one hand, for creation of a distance course with the set didactic characteristics; on the other hand, for an objective assessment of the current and total results of training on the basis of which training course management is based.

In distance learning systems training assimilation course degree is estimated by student testing results (J.Myrick, 2010). Now much attention is paid on the increase of accuracy of an assessment of student results in distance learning systems. In work (A.A.Rybanov, 2013a) for this purpose it is offered to consider process of user formation of the final answer to tasks in a test form, and in work (K.Scalise, B.Gifford, 2006) it is offered innovative tasks forms for computer knowledge testing.

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At the same time a problem of development of technology of an aprioristic objective assessment of distance course theme's complexity remains actual.

2. Problem definition

The integrated assessment of distance course assimilation quality, as a rule is calculated on the basis of the student's marks received as a result of passing of all training course tasks. For example, in Moodle system (S.S.Nash, W.Rice, 2010) there are such approaches to calculate the integrated training course assimilation quality assessment (A.A.Rybanov, 2013b) as: an average of mark, the weighed average of marks, a median of marks, the lowest mark, the highest marks, mode of marks, the sum of marks.

We will consider approaches to calculate of an integrated assessment of assimilation quality on the following example. Let the user of distance learning system received as results of test tasks on distance course themes the following marks (on a hundred-mark scale): (85, 78, 65, 76, 78, 73, 80, 82, 83, 77, 62, 78, 65).

Then, the integrated assessment can be calculated by the following methods:

1) The average of marks – the sum of all estimates on subjects shares on total of estimates:

$$(85+78+65+76+78+73+80+82+83+77+62+78+65) / 13 = 75.85 \quad (1)$$

2) The weighed average of marks – for each subject can be put in compliance the weight which will reflect its importance in calculation of a result. The sum of weighs of all marks has to be equal 1. In this case the result is calculated as follows: the values of each element of mark increased by its weight are summarized:

(85*0.04+78*0.15+65*0.08+76*0.07+78*0.08+73*0.04+80*0.08+82*0.06+83*0.06+77*0.1+62*0.08+78*0.09+65*0.07) = 75.63 (2)

The problem consists in objective purpose of theme weighs.

3) A median of marks – the central mark (or an average from two central) from the list sorted by increase:

(62, 65, 65, 73, 76, 77, 78, 78, 78, 80, 82, 83, 85) = 78 (3)

Advantage before an average is that the median can't be influenced by marks which are too far from an average.

4) The lowest mark – the smallest mark after normalization:

min(62, 65, 65, 73, 76, 77, 78, 78, 78, 80, 82, 83, 85) = 62 (4)

5) The highest mark – the greatest mark after normalization:

max(62, 65, 65, 73, 76, 77, 78, 78, 80, 82, 82, 83, 85) = 85 (5)

6) Mode of marks – the most often found mark.

mode(62, 65, 65, 73, 76, 77, 78, 78, 78, 80, 82, 83, 85) = 78 (6)

This strategy is more often used with non-numerical marks. Advantage before an average is that the mode can't be influenced by marks which are too far from an average. However this strategy loses the meaning if some estimates often meet (only one will get to a result or all marks).

7) The sum of marks – the sum of all values of marks:

(85+78+65+76+78+73+80+82+83+77+62+78+65)=986 (7)

From all approaches, only "the weighed value of estimates" considers distance course theme's complexity by determination of test weight coefficient associated with this module. There is a problem of a marks choice of educational modules within a distance course.

As evidence-based approach to define distance course theme's weighs T. Saati's algorithm can be used (B.L.Golden, E.A.Wasil, P.T.Harker, 1989).

3. Mathematical Description

3.1 Application of Saati's algorithm for determination of distance course theme's complexity weight coefficients

Question of using such method as objects couples assessment on similarity degree for process of scaling are discussed in work of psychologist (J.P.Guilford, 1954). The method of paired comparisons can be also successfully applied to the objects forming distance course structure.

T. Saati's algorithm is based on the autonomous comparison of distance course theme's complexity which is carried out by one expert. For each distance course theme couple the expert specifies in what degree one of them is more difficult another. IDEF0 model of procedure of making decision on set of distance course theme's weights is presented at fig. 1.

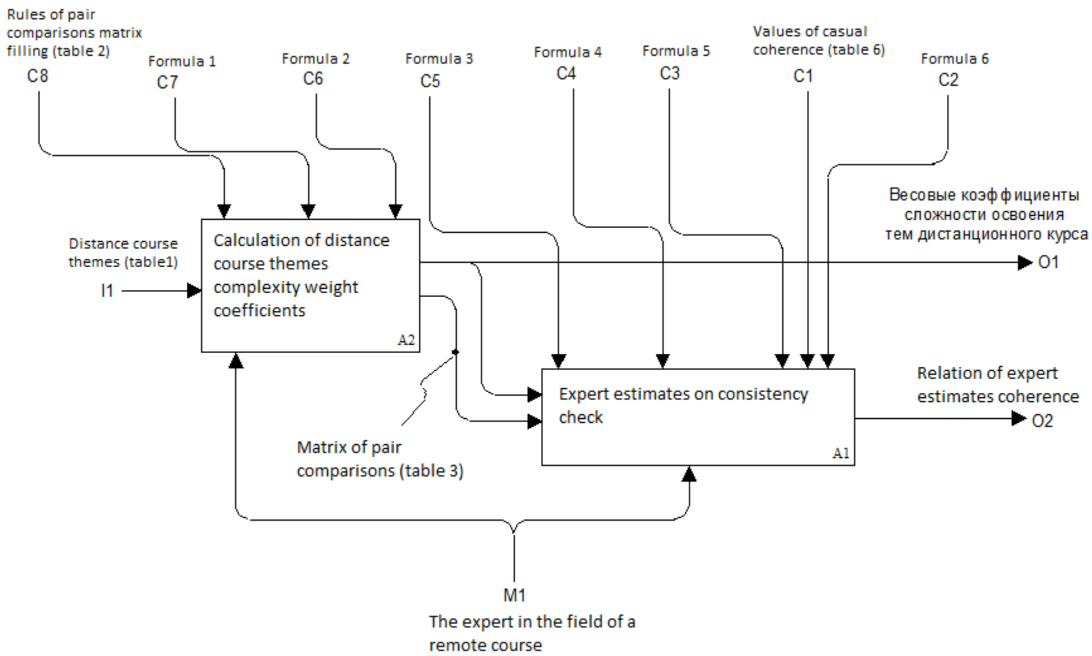

Fig.1. IDEF0 model of procedure of making decision on set of distance course theme's weights

We will consider application of this method on the following example: it is necessary to determine theme complexity weight of the distance course "Machine-dependent Languages" on the basis of consultation with the expert. Lecture's themes of a training course "Machine-dependent languages" are presented in the table 1.

Table 1. Lecture's themes of a training course "Machine-dependent languages"

No. of a distance course theme	Name of a lecture's themes
A_1	Introduction. Purposes and problems of discipline
A_2	Program model of the INTEL 8080 microprocessor, registers
A_3	Formats and systems of commands, addressing methods
A_4	Commands of transfer of data and work with a stack
A_5	Arithmetic commands
A_6	Commands of comparison
A_7	Logical commands and commands of shift
A_8	Introduction to the description of a line format and chain Commands
A_9	General information about work of chain commands
A_{10}	Chain commands
A_{11}	Introduction. Coprocessors. Ways of exchange of information between the central processing unit and the coprocessor
A_{12}	Commands of the mathematical coprocessor
A_{13}	Mathematical coprocessor

IDEF0 model of distance course theme's complexity weight coefficients calculation procedure presented at fig. 2.

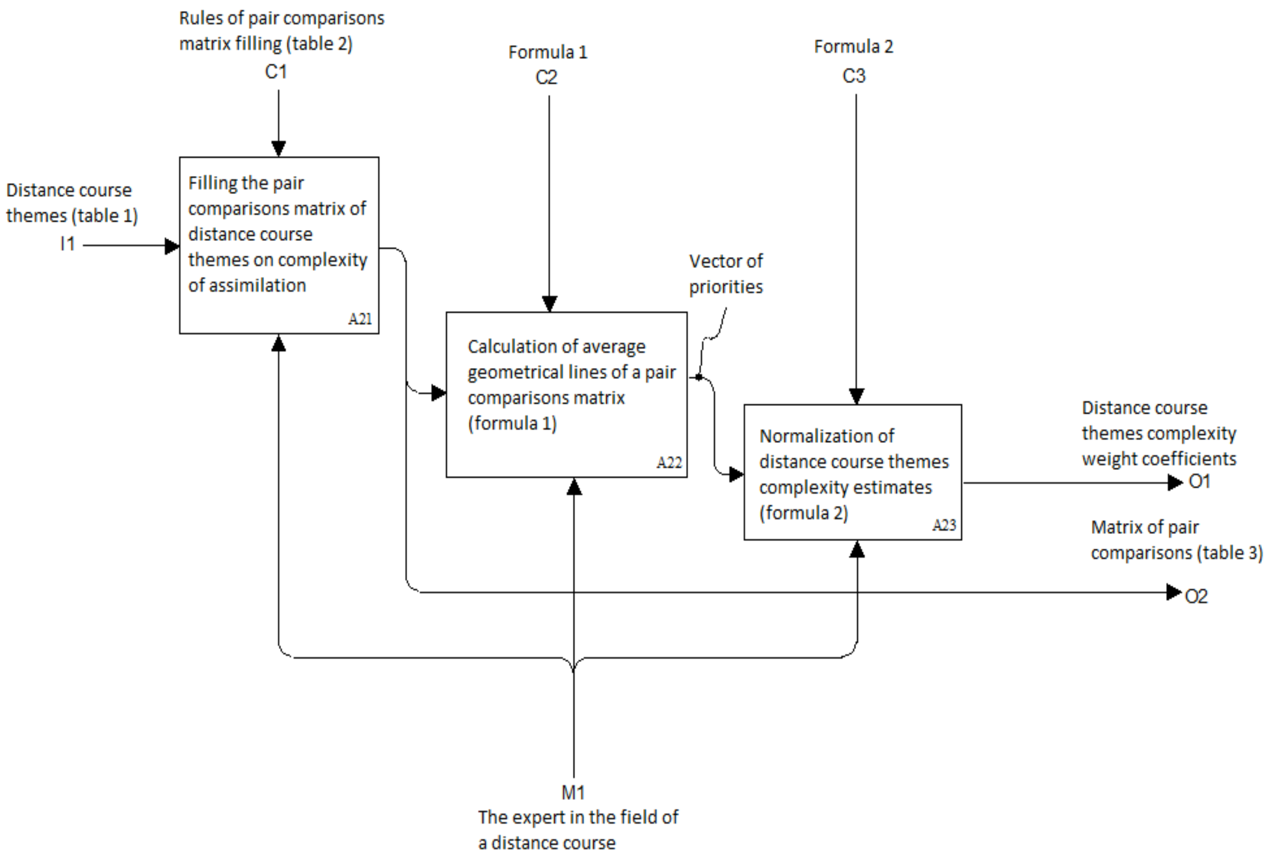

Fig. 2.IDEF0 model of distance course theme's complexity weight coefficients calculation procedure

Calculation of distance course theme's complexity weight coefficients is carried out in the following order:

1. The expert fills a matrix of pair comparisons with the n x n size, where n – quantity of a training course themes. The matrix is filled by the rules provided in the table: 2.

Table 2. Lecture's themes of a training course "Machine-dependent languages"

x_{ij}	Value
1	A_i and A_j subjects have approximately identical complexity
3	A_i a subject am a little more difficult than A_j
5	A_i a subject am more difficult than A_j
7	A_i a subject am much more difficult than A_j
9	A_i subject obviously more difficult A_j

If theme i is easier than j then the return estimates are specified (1/3, 1/5, 1/7, 1/9). Intermediate estimates can be used (2, 4, 6, 8 and 1/2, 1/4, 1/6, 1/8), for example, if theme i is very little more difficult than j, it is possible to use assessment $x_{ij} = 2$ (then $x_{ji} = 1/2$). On the main diagonal ones are put.

Let the expert filled a pair comparisons matrix of a distance course theme as follows (the table: 3)

.

Table 3. Pair comparisons Matrix of a distance course theme "Machine-dependent Languages" on complexity of assimilation

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}	A_{13}
A_1	1	1/7	1/7	1/5	1/5	1/3	1/3	1	1/3	1/5	1/3	1/7	1/9
A_2	7	1	1/3	1	1/3	1	3	3	1	1	1	1/3	1/5
A_3	7	3	1	3	5	3	5	7	5	3	3	1	1/3
A_4	5	1	1/3	1	3	1	5	5	3	3	3	1/3	1/5
A_5	3	3	1/5	1/3	1	1	3	3	3	1	1/3	1/5	1/7
A_6	3	1	1/3	1	1	1	3	3	3	1	1	1/3	1/5
A_7	3	1/3	1/5	1/5	1/3	1/3	1	1/3	1/3	1/5	1/3	1/5	1/7
A_8	1	1/3	1/7	1/5	1/3	1/3	3	1	1/3	1/5	1/5	1/7	1/9
A_9	3	1	1/5	1/3	1/3	1/3	3	3	1	1/3	1/3	1/5	1/7
A_{10}	5	1	1/3	1/3	1	1	5	5	3	1	1/3	1/5	1/7
A_{11}	3	1	1/3	1/3	3	1	3	5	3	3	1	1/3	1/5
A_{12}	7	3	1	3	5	3	5	7	5	5	3	1	1/3
A_{13}	9	5	3	5	7	5	7	9	7	7	5	3	1

Here, for example, the x_{21}=7 element means that the theme A_2, according to the expert, is much more difficult for assimilation, than the subject A_1. The x_{53}=1/5 element means that the theme A_5 is easier, than the theme A_3.

2. We calculate a distance course theme complexity estimates – averages geometrical lines of a pair comparisons matrix:

$$k_i = \sqrt[n]{\prod_{j=1}^{n} x_{ij}}, \tag{8}$$

where n – quantity of training course themes.

The average geometrical calculation algorithm consists of the following steps:

1) multiply elements of every line and we write down the received results in a column;

2) take a n-degree root from each element of the found column;

3) summarize elements of this column;

4) divide each of these elements into the calculated sum.

The normalized assessment for theme iis calculated by the following formula:

$$\hat{k}_i = \frac{k_i}{\sum_{j=1}^{n} k_j}, \tag{9}$$

wherei – designation of a subject on a line in a pair comparisons matrix.

Using way of approximate calculation of own pair comparisons matrix elements, we calculate own column (a vector of priorities) for considered distance course themes. Further it is necessary to carry out operation of a vector of priorities normalization that is reflected in the table: 4.

Table 4. The normalized complexity estimates of the distance course themes

Distance course theme	**Vector of priorities** k_i	**The normalized complexity estimates of the distance course themes** $\hat{k}_i$
A_1	0.273	0.014
A_2	0.941	0.049
A_3	2.740	0.143
A_4	1.514	0.079
A_5	0.863	0.045
A_6	1.045	0.054
A_7	0.342	0.018
A_8	0.333	0.017
A_9	0.565	0.032
A_{10}	0.928	0.048
A_{11}	1.810	0.094
A_{12}	2.850	0.149
A_{13}	4.958	0.258

The normalized estimates of a vector of priorities are the complexity estimates of the distance course themes. The considered approach corresponds to procedure of objects relative importance establishment for T. Saati's method.

3.2 Expert estimates check of on consistency

For this method check of expert estimates on consistency is possible. IDEF0 model of procedure of expert estimates check on consistency is given in fig. 3.

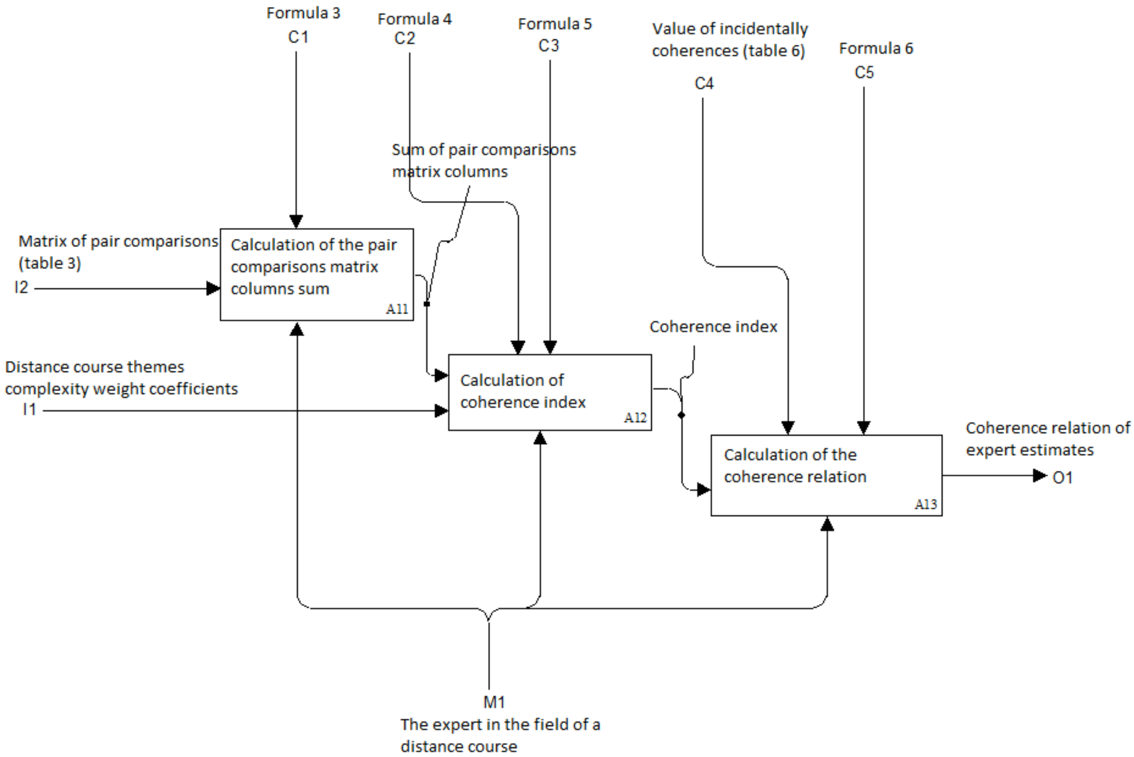

Fig. 3.IDEF0 model of procedure of expert estimates check on consistency

This check allows revealing mistakes which the expert when filling a matrix of pair comparisons could make. Mistakes (contradiction) can be one of the following: for example, the expert specifies that the subject A_1 is easier A_2, the subject A_2 is easier A_3, and at the same time the subject A_1 is more difficult than A_3. We will consider check on consistency for a problem of definition of themes complexity weight coefficients of the distance course "Machine-dependent Languages":

1. We find the sums of pair comparisons matrix columns (the table: 5):

$$M_j = \sum_{k=1}^{n} x_{kj} \,. \tag{10}$$

Table 5. Sum of pair comparisons matrix columns

Distance course theme	M_j
A_1	57.00
A_2	20.81
A_3	7.55
A_4	15.93
A_5	27.67
A_6	18.33
A_7	46.33
A_8	52.33
A_9	35.00
A_{10}	25.93
A_{11}	18.87
A_{12}	7.48
A_{13}	3.26

2. We count auxiliary value L by summation of multiplication of the matrix columns sums on distance course theme's complexity weights:

$$L = \sum_{i=1}^{n} k_i \cdot M_i \,. \tag{11}$$

For this example L = 14.02.

3. We find the value called by a coherence index (CI):

$$CI = \frac{L-n}{n-1} \,. \tag{12}$$

For this example CI = 0.09.

4. Value of casual coherence depends on dimension of a pair comparisons matrix (CaC). Values for dimension matrixes from 3 to 10 are given in the table: 6.

Table 6. Values of casual coherence

Dimension of a matrix	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
CaC	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

In work (H.A.Donegan, F.J.Dodd, 1991) there is an expanded statistically significant set of values of an casual coherence index which is used in a T. Saati method of the hierarchies analysis for determination of distance course theme's weight coefficients. In his example (for n = 13) CaC= 1.56.

5. We find the coherence relation:

$$CR = \frac{CI}{CaC} \,. \tag{13}$$

If the relation of coherence exceeds 0.2, specification of a pair comparisons matrix is required.

In this example CR= 0.09/1.56 =0.05, therefore, specification of expert estimates in this case isn't required.

Thus, "Machine-dependent languages" distance course theme's complexity weights were received (table: 4), and can be used in a formula of exposure of a total assessment at all course:

$$TA = \sum_{i=1}^{n} \hat{k}_i \cdot \hat{I}_i \,, \tag{14}$$

Where TA – a total assessment on a training course; O_i – a total assessment by results of testing on theme i of a training course; $\hat{k}_i$ – complexity weight of theme i of a training course.

Weight coefficients for distance courses on disciplines the "Machine-dependent languages" calculated on T. Saati's algorithm are given in fig. 4.

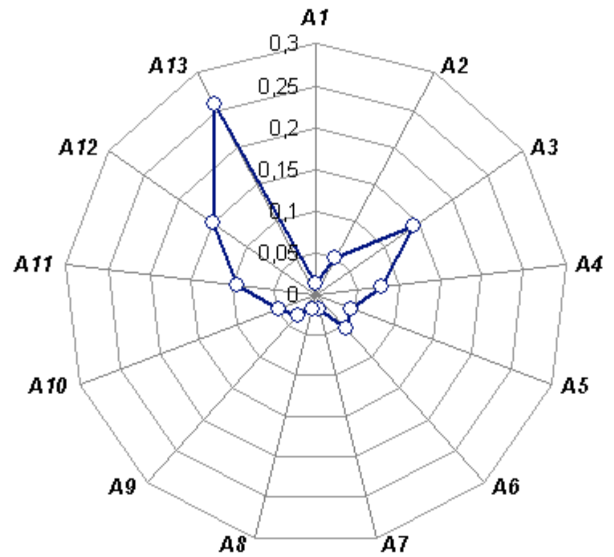

Fig. 4. Theme complexity weight coefficients of distance course "Machine-dependent Languages"

4. Results and discussion

4.1 Comparative analysis of ontologic representation of distance course themes and their complexity weight coefficients

The purpose of experiment is check of compliance between complexity of ontologic representation of distance course themes and their weight coefficients calculated on T. Saati's algorithm.

The ontological model of a training course is represented in the form of the semantic network corresponding to the formal description of semantics of a set of educational modules.

The semantic description of the educational module of discipline (training course) can be provided in the following structure:

$$M = < I, U, Q, T, R_1, R_2, R_3 >, \tag{15}$$

where I – element of the educational module (quantum of educational information); U – set of inter-element relationship of the educational module; Q – set of types of elements of the educational module: { concept, law, explanation, additional data }; T - set of relationship types between information items (is-a, part-of, base-on); R_1 - the incidence relation on a set I×U; R_2 - the incidence relation on a set I×Q; R_3 - the incidence relation on a set U×T.

In fig. 5 – 7 the examples of ontologic models constructed on the themes A_2, A_5, A_7 of the distance course "Machine-dependent Languages" are presented. In these models the top is concept of a subject of distance course theme, and an arch – communication between concepts. Color of an arch characterizes communication type.

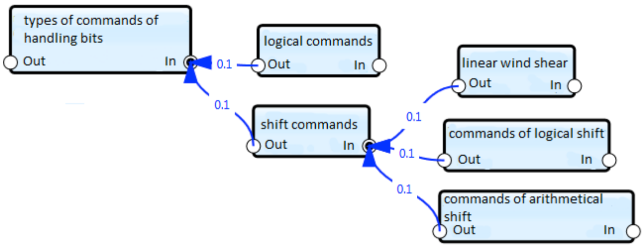

Fig. 5. Ontologic model of the theme A_7 (complexity of a theme on T. Saati's algorithm is equal 0.018)

For an assessment of understanding complexity of ontologic models in works (D.Bonchev, G.A.Buck, 2005) and (A.Lozano-Tello, A.Gomez-Perez, 2004) it is recommended to use quantitative measures of semantic networks.

In table 7 calculated values of the following measures (A.Gangemi, C.Catenacci, M.Ciaramita, J.Lehmann, 2005) for ontologic models of all themes of the distance course "Machine-dependent Languages" are given:

1. Ingwe-Miller's measures (D.Bonchev, G.A.Buck, 2005):
- Relation of quantity of tops with normal degree to all tops (M_1);
- Average graph top degree (M_2);
- Median graph top degree (M_3);
- Mean square deviation of top degree (M_4).

2. Measures of ontology communications number variety:
- Quantity of different communication types (M_5);
- The normalized quantity of different communication types (M_6).

3. Measures for depth:
- Absolute depth (M_7);
- Average depth (M_8);
- Maximal depth (M_9);
- Median of depth (M_{10});
- Mean square deviation of depth (M_{11});
- An average square deviation of depth on the relation to the average depth (M_{12}).

4. Measures for breadth:
- Absolute breadth (M_{13});
- Average breadth (M_{14});
- Maximal breadth (M_{15}).

5. Ontology complexity measures:
- Quantity of tops with multiple inheritance in relation to a set of all graph tops (M_{16});
- Average quantity of parental tops at graph top (M_{17}).

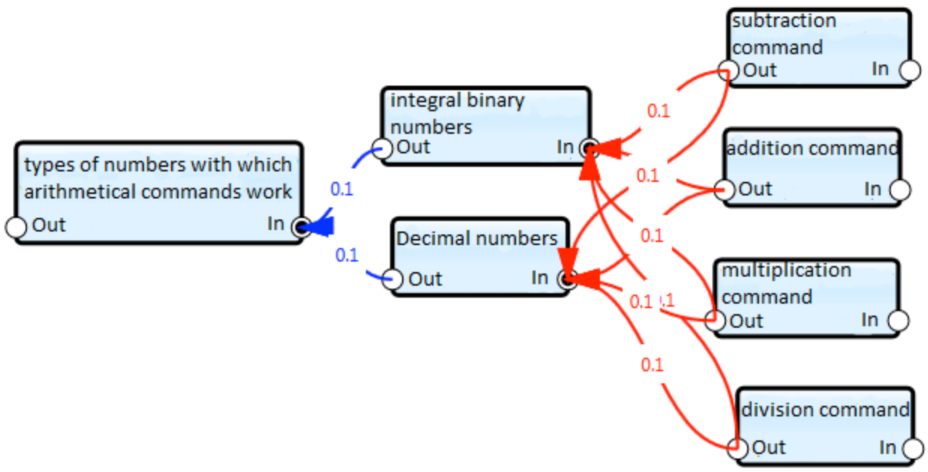

Fig. 6. Ontologic model of the theme A_5 (complexity of a theme on T. Saati's algorithm is equal 0.045)

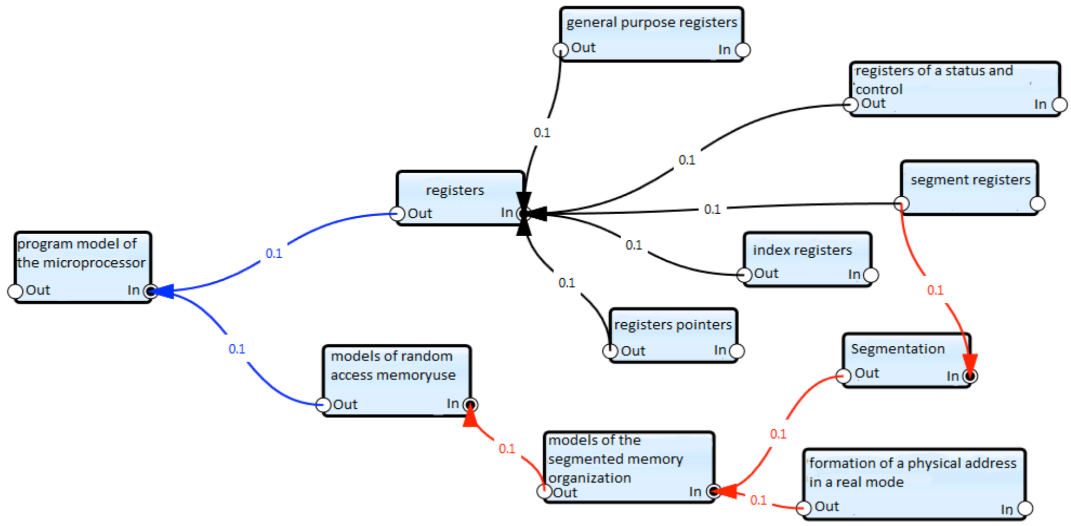

Fig. 7. Ontologic model of the theme A_2 (complexity of a theme on T. Saati's algorithm is equal 0.049)

Table 7. Values of quality measures for ontologic models of themes of the distance course "Machine-dependent Languages"

Measures for ontologic model	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}	A_{13}
Ingwe-Miller's measures													
M_1	2.00	1.00	1.00	1.50	0.70	1.50	1.20	2.00	2.00	1.25	1.33	0.78	0.50
M_2	1.00	2.00	2.00	1.33	2.86	1.33	1.67	1.00	1.00	1.60	1.50	2.57	4.00
M_3	1.00	2.00	1.00	1.00	2.00	1.00	1.00	1.00	1.00	2.00	1.50	2.00	3.50
M_4	0.00	2.00	3.27	0.67	2.14	0.33	1.47	0.00	0.00	0.30	0.33	1.95	3.56
Measures of ontology communications number variety													
M_5	1.00	3.00	3.00	1.00	2.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	3.00
M_6	0.50	0.27	0.25	0.17	0.29	0.33	0.17	0.50	0.50	0.20	0.25	0.29	0.30
Measures for depth													
M_7	2.00	24.00	37.00	8.00	24.00	3.00	11.00	2.00	2.00	5.00	4.00	16.00	136.0
M_8	2.00	3.43	4.63	2.00	3.00	3.00	2.75	2.00	2.00	5.00	4.00	4.00	4.86
M_9	2.00	5.00	6.00	2.00	3.00	3.00	3.00	2.00	2.00	5.00	4.00	4.00	6.00
M_{10}	2.00	3.00	5.00	2.00	3.00	3.00	3.00	2.00	2.00	5.00	4.00	4.00	5.00
M_{11}	0.00	0.62	1.13	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.42
M_{12}	0.00	0.18	0.24	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.09
Measures for breadth													
M_{13}	2.00	12.00	13.00	6.00	7.00	3.00	6.00	2.00	2.00	5.00	4.00	7.00	21.00
M_{14}	1.00	2.00	2.00	3.00	2.00	1.00	2.00	1.00	1.00	1.00	1.00	1.00	3.00
M_{15}	1.00	6.00	6.00	4.00	4.00	1.00	3.00	1.00	1.00	1.00	1.00	4.00	7.00
Ontology complexity measures													
M_{16}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M_{17}	0.50	1.00	1.00	0.67	1.43	0.67	0.83	0.50	0.50	0.80	0.75	1.29	2.00

The analysis of fig. 5 – 7 and these tables: 4 and 7 allows to make the following conclusion: if ontologic model complexity of the theme Ai is more than ontologic model complexity of the theme Aj , then complexity weight coefficient of on T. Saati's algorithm for the theme Ai is more, than for the theme Aj.

4.2 Comparative analysis of distance course theme's legibility and their complexity weight coefficients

The purpose of experiment is check of compliance between distance course theme's legibility and their weight coefficients calculated on T. Saati's algorithm.

Legibility – the property of text material characterizing ease of its perception by person. Legibility of the text of a distance course theme is one of those properties which promotes more successful assimilation training material by student. Therefore, the received estimates of distance course theme's complexity coefficients have to correlate with values of legibility of their texts.

In the table: 8 the values of texts legibility for themes of the distance course "Machine-dependent Language" calculated on the Flash formula are given (R.Flesh, 1974).

Table 8. Values of texts legibility for themes of the distance course "Machine-dependent Language"

Distance course theme	Flash reading ease
A_1	82.751
A_2	75.613
A_3	35.861
A_4	55.081
A_5	79.162
A_6	41.513
A_7	80.157
A_8	73.157
A_9	41.198
A_{10}	53.288
A_{11}	48.573
A_{12}	37.833
A_{13}	15.743

In fig. 8 the graph of correlation of text legibility and complexity of distance course theme's assimilation is shown. The correlation coefficient between text legibility of a distance course theme and complexity of its assimilation is equal-0.811 that confirms a solvency of the received complexity coefficients for distance course themes.

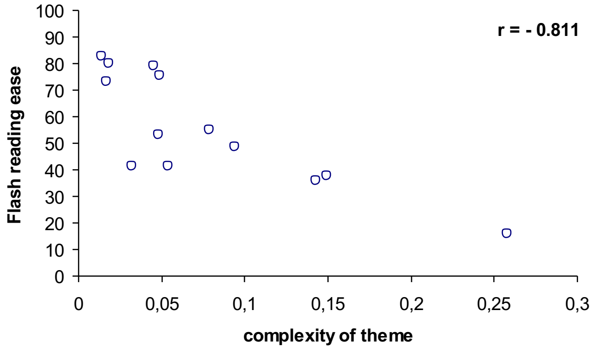

Fig. 8. Graph of correlation of legibility of the text and complexity of distance course theme's assimilation

5. Conclusion

The considered approach of determination of distance course theme's complexity weight coefficients on the basis of T. Saati's algorithm can be used in different distance training and control systems to increase the accuracy of measurement of the knowledge gained by users. The received distance course theme's weight coefficients can be used as target indicators for problems of a clustering and classification distance course themes by such entrance indicators as quantitative criteria of quantization quality of a training course and quantitative metrics of training course complexity.

Thus for ensuring unambiguity of estimates and convenience of practical use procedure of estimation has to be realized at the technological level with application of information and communication technologies means (ICT).

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