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The method of the student conceptual knowledge evaluation in the intellectual learning computer system

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Galiamova E. V., Karpenko A.P., Sokolov N.K.

Bauman Moscow State Technical University, 105005, Moscow, Russian Federation
sokolov@bmstu.ru
karpenko@pk6.bmstu.ru
galiamova@bmstu.ru

I. *Introduction*

Modern learning computer systems are an intellectual systems developed on the basis of paradigm of knowledge searching, analyzing and creation (manipulation). In this case the formalization of the subject field's ontology is made as a knowledge database which could be realized using one of the following knowledge models: production models [1], semantic networks [2], frame models or formal logical models [3].

In this work we are developing learning system's knowledge database as a semantic network, which consists of learning discipline's subject field concepts and relationships between the concepts. The above mentioned semantic net has been drawn in this article as a directed graph where the nodes represent the concepts of the learning subjects and the graph edges represent the type of the semantic relationships between two nodes.

During the learning process the student understands different parts of the course, but he does not manage the full conceptual set of concepts of the discipline. In such case the level of course comprehension could not be evaluated as a suitable. Because of this the main task of the modern learning systems is a comprehension support and control, for example, how the student understood the main concepts of the subject [3].

In order to formalize the students' knowledge about conceptual set of the learning course we propose to use cognitive map [4]. Every cognitive map formalizes the student's comprehension about the concept viewed as a graph, which corresponds ideally to sub graph of the learned course semantic net. Thus, the control over the student's comprehension of every concept is leads to comparison between sub graph in the framework of semantic net and the graph which is described by represented student's cognitive map [5].

Note that such approach should be considered together with one central task of ontology development – the problem of ontology mapping [6]. The main concept in the ontology development is an ontology mapping, that means the process of relationships establishment between few ontology or, in other words, semantic correspondence mining between similar elements from different ontology.

The semantic model used in this article has been considered in [7, 8]. This paper considers the model of student comprehension knowledge about learning course's concepts as a cognitive maps as well as some metrics for comparison the sub graphs which relay to the cognitive maps of the learning student.

Realization. The realization of the proposed method plans to be applied to the instrumental learning system BIGOR (http://bigor.bmstu.ru) [9].

II. *Preliminaries*

The *input concept* c_i of the proper module we argue a concept the definition of which has been given in some other module of the course or any other course. Analogously, the *output concept* c_j of given module we call the concept, the definition of which has been given in that module.

Every output concept c_j is defined with use of input concepts or/and output concepts. We call the input and output concepts as informatively linked with the concept c_j in common use [7].

The set of all concepts which are *informatively linked* with the concept c_j including the concept c_j itself, which could be pointed as $\{c_j\}$. The number of concepts in the set $\{c_j\}$ could be defined as n_j.

Every concept $c_j \in \{c_i\},\ i \neq j$ has its own complexity $\mu(c_j) = \mu_j \geq 0$. The concept's complexity could be accounted as an additive sum of input concepts proposed in [7]. The total sum of set of all concepts' complexities we call $\{\mu(c_i)\} = \{\mu_i\}$.

In the set of concepts $\{c_i\}$ there are a finite set of relationships $R_0, R_1, \dots R_r$, where R_0 - is a relationship "defining concept – defined concept" [3]. The set of relationships, which connects the concepts $c_j, c_k \in \{c_i\}, j \neq k$ we call as $\{R_{j,k}\} = R_{j,k,0}, R_{j,k,1}, R_{j,k,2}, \dots$ where always $R_{j,k,0} = R_0$. Let us the number of relationships equal m_i. It could be mentioned that the number of relationships in set $\{R_i\}$ is not always equal to all relationships $\{R_j\} = R_0, R_1, R_2, \dots$

There is a value of relationship $v(R_j)$, which formalizes the weight of this relationship in comparison with other relationships. We agree that $v(R_j) \geq 0$ for every $j \in [0{:}r]$. The set of weights $\{V_{i,j}\}$ of all relationships which connect concepts $c_{j,k} \in \{c_i\}$, where $j \neq k$.

Semantic net $SS(c_i) = SS_i$ for concept c_i, is defined by the set of concepts $\{c_i\}$, by measures of complexity of these concepts $\{\mu_i\}$, by set of relationships $\{R_i\}$ as well as by their weights $\{V_i\}$:

$$SS_i = \langle \{c_i\}, \{R_i\}, \{\mu_i\}, \{V_i\} \rangle.$$

Semantic net $SS(c_i)$ could be represent as a weighted directed multi-graph G_i without circuits, the nodes of the graph represent concepts, the edges represent relationships between concepts and weights of nodes represent complexity's measures, and the weights of edges represent the weights of relationships.

The task for this work is following:

- to develop the model of student understanding about the given semantic net made as correspondent cognitive map CM_i;
- to propose comparison metrics to compare semantic net SS_i with the cognitive map CM_i, which represent the level of student's comprehension about the concept c_i.

III. *Cognitive map model*

Originally the concept "cognitive map" appeared in psychology and was connected to the features of the human's environment cognition. According to traditional approach the cognitive map means formalized subjective idea about the spatially organized environment [4]. To wide extent the cognitive map does not connect to spatially organized environment of the man, but it formalizes man's ideas about some problem field, that is the cognitive map is a certain image or form of internal man's ideas about this knowledge domain.

The main elements of the cognitive map are basic factors (in other words – factors, concepts, parameters, variables) and relationships between them.

Let us define the cognitive map CM_i corresponding with concept c_i as a cortege (ordered sequence):

$$CM_i = \langle \{\overline{c_\iota}\}, \overline{\{R_\iota\}} \rangle,$$

where

$\{\overline{c_\iota}\}$ - a set of concepts including the concept c_i, which were pointed in the cognitive map CM_i as concepts linked with concept c_i;

$\{\overline{R_\iota}\}$ - a set of relationships from the cortege $R_0, R_1, \dots, R_r, \dots$.

The number of concepts in the set $\{\overline{c_\iota}\}$ is defined as $\overline{n_\iota}$, and a number of relationships in the set $\{\overline{R_\iota}\}$ is defined as $\overline{m_\iota}$.

Take into account, that in common case $n_i \neq m_i$.

The cognitive map CM_i is represented as an directed multi graph without back loops $\tilde{G}_i$, the vertexes are correspondent to concepts $\{\overline{c_\iota}\}$ and edges correspondent to relationships $\{\overline{R_\iota}\}$.

Supposing that the above mentioned information consisting in the cognitive map CM_i, has been obtained (by certain way) from the student.

IV. *Learning quality metrics*

The students' comprehension of concept c_i quality metric $\rho(c_i,\widetilde{c_i})$ is defined as a similarity measure between the graph G_i of the semantic net SS_i and graph $\tilde{G}_i$, of the cognitive map CM_i.

A lot of such kind metrics could be proposed, which use the complexity measures [9] of the concepts $\{c_i\}$ and the measures of weights $\{V_{i,j}\}$, as well as without usage of them.

4.1. The learning quality metrics without complexity and weight measures

Metric 1

The quality metric $\rho_1(c_i,\widetilde{c_i})$ is defined as a number of concepts n_i^T from the set $\{\overline{c_i}\}$, which are also consist in the set $\{c_i\}$, that is

$$\rho_1(c_i,\widetilde{c_i}) = n_i^T. \qquad , \qquad (1)$$

The value of the metric $\rho_1(c_i,\widetilde{c_i})$ is a number of concepts which have been pointed by student correctly as concepts linked with concept c_i .

Metric 2

The quality metric $\rho_2(c_i,\widetilde{c_i})$ is defined as a weighted difference between the number of correctly pointed concepts n_i^T from the set $\{\overline{c_i}\}$, and a number of incorrectly pointed concepts n_i^F from the set $\{\overline{c_i}\}$:

$$\rho_2(c_i,\widetilde{c_i}) = \rho_2(\alpha,\ c_i,\widetilde{c_i}) = n_i^T - \alpha\, n_i^F, \qquad (2)$$

where $\alpha \epsilon [0,1]$ - the weight coefficient.

Notes:

1. The number of incorrectly pointed concepts consists of concepts from the set of concepts $\{c_i\}$ not included into the set $\{\overline{c_i}\}$ as well as from the set of concepts from the set $\{\widetilde{c_i}\}$ not included into the set $\{c_i\}$.
2. The metric (2) and other similar metrics are double criterion so the weight multiplayer α defines the weights of the correspondent optimal criteria.

Metric 3

The quality metric $\rho_3(c_i,\widetilde{c_i})$ is defined as number of correctly pointed relationships m_i^T from the set $\{\tilde{R}_i\}$, which consist in the set $\{R_i\}$:

$$\rho_3(c_i,\widetilde{c_i}) = m_i^T \qquad (3)$$

Metric 4

The quality metric $\rho_4(c_i, \widetilde{c_i})$ is analogous to quality metric $\rho_2(c_i, \widetilde{c_i})$ and defined as weight difference between the number of correctly pointed relationships m_i^T from the set $\{\overline{c_i}\}$, and a number of incorrectly pointed concepts m_i^F from the set $\{\overline{c_i}\}$:

$$\rho_4(c_i, \widetilde{c_i}) = \rho_4(\beta, \ c_i, \widetilde{c_i}) = m_i^T - \beta \, m_i^F, \quad (4)$$

Where $\beta \epsilon [0,1]$ - the weight coefficient.

Note. The number of incorrectly pointed relationships of concepts from the set of relationships $\{R_i\}$ not included into the set $\{\tilde{R}_i\}$ as well as the relationships from the set of relationships $\{\tilde{R}_i\}$ not included into the set $\{R_i\}$. The number of incorrectly pointed relationships includes also the relationships which connect the improper concepts from the cognitive map.

Metric 5

The quality metric $\rho_5(c_i, \widetilde{c_i})$ is defined as an additive parcel of metrics (1) – (4), that is:

$$\rho_5(c_i, \widetilde{c_i}) = \rho_5(\alpha, \beta, c_i, \widetilde{c_i}) = \sum_{j=1}^{4} \lambda_j \rho_j \, (c_i, \widetilde{c_i}) \, , \quad (5)$$

where $\alpha, \beta, \lambda \epsilon [0,1]$ - the weight coefficients.

Note. The values of the metrics (1) – (4) have different signs and scale. Therefore it is useful to use standardized values of the above mentioned metrics:

$$\tilde{\rho}_j(c_i, \tilde{c}_i) = \frac{\rho_j(c_i,\tilde{c}_i) - \rho_j^{min}(c_i,\tilde{c}_i)}{\rho_j^{max}(c_i,\tilde{c}_i) - \rho_j^{min}(c_i,\tilde{c}_i)} \in [0,1], \quad j \in [1:4] \quad (6)$$

The parameters $\rho_j^{max}(c_i, \tilde{c}_i), \rho_j^{min}(c_i, \tilde{c}_i)$ - the minimum and maximum possible values of metrics (1) – (4) correspondently.

It is easy to see, that

$$\rho_1^{max}(c_i, \tilde{c}_i) = n_i; \ \ \rho_1^{min}(c_i, \tilde{c}_i) = 0,$$

$$\rho_2^{max}(c_i, \tilde{c}_i) = n_i; \ \ \rho_2^{min}(c_i, \tilde{c}_i) = -\alpha n_i,$$

$$\rho_3^{max}(c_i, \tilde{c}_i) = m_i; \ \ \rho_3^{min}(c_i, \tilde{c}_i) = 0,$$

$$\rho_4^{max}(c_i, \tilde{c}_i) = m_i; \ \ \rho_4^{min}(c_i, \tilde{c}_i) = - \ \alpha m_i.$$

Based on the standardized metrics (6) different linear and nonlinear scales for the learning quality estimation could be drawn. For example, M-marks (M=5) linear scale is represented in table 1, where $\Delta\rho = \frac{1}{M}$.

Table 1. Learning quality estimation table (number of marks – 5)

Mark	**Value range $\widetilde{\rho}_j(c_i, \widetilde{c_i})$**
1	$[0:\Delta\rho] = [0:0{,}2]$
2	$[\Delta\rho:2\Delta\rho] = [0{,}2:0{,}4]$
3	$[2\Delta\rho:3\Delta\rho] = [0{,}4:0{,}6]$
4	$[3\Delta\rho:4\Delta\rho] = [0{,}6:0{,}8]$
5	$[4\Delta\rho:5\Delta\rho] = [0{,}8:1{,}0]$

Notes:

1. It could be propose a lot of different metrics which will be a modification of the above mentioned metrics. For example, in metric (2) the concepts included into set $\{c_i\}$ not included into the set $\{\widetilde{c_i}\}$ could be considered separately (with different weights) as well as the concepts included into set $\{\widetilde{c_i}\}$ not included into the set $\{c_i\}$.

2. In metric (4) it could be considered three types of relationships:

   a. the relationships of concepts from the set of relationships $\{R_i\}$ not included into the set $\{\tilde{R}_i\}$;

   b. the relationships of concepts from the set of relationships $\{\tilde{R}_i\}$ not included into the set $\{R_i\}$;

   c. the relationships that connect improperly defined concepts in the cognitive map.

4.2. The learning quality metrics with complexity and weight measures

Metric 6

The quality metric $\rho_6(c_i, \widetilde{c_i})$ is analogous to metric (1) and is defined as a weighted number of correctly pointed concepts from the set $\{\widetilde{c_i}\}$:

$$\rho_6(c_i, \widetilde{c_i}) = \sum_j \mu_j(c_j), \quad j \in \{j_i\}^T \qquad (7),$$

where

$\{j_i\}^T$ - a set of indexes of correctly pointed concepts from the set $\{\widetilde{c_i}\}$. It is easy to see that the maximum number equal to n_i^T.

Metric 7

The quality metric $\rho_6(c_i,\tilde{c_i})$ is analogous to metric (2) and is defined as a difference between weighted number of correctly pointed and incorrectly pointed concepts from the set $\{\tilde{c_i}\}$:

$$\rho_7(c_i,\tilde{c_i}) = \rho_7(\delta, c_i,\tilde{c_i}) = \rho_6(c_i,\tilde{c_i}) - \delta \sum_j \mu\left(c_{i,j}\right), \; j \in \{j_i\}^F \tag{8}$$

where $\delta\epsilon[0,1]$ - the weight coefficient, $\{j_i\}^F$ - a set of incorrectly pointed concepts from the set $\{\tilde{c_i}\}$. It is easy to see that the maximum number equal to n_i^F.

Metric 8

The quality metric $\rho_8(c_i,\tilde{c_i})$ is analogous to metric (3) and is defined as weighted number of correctly pointed relationships of concepts from the set of relationships $\{\tilde{R}_i\}$:

$$\rho_8(c_i,\tilde{c_i}) = \sum_{j,k,l} v\left(R_{j,k,l}\right), \; (j,k,l) \in \{j,k,l\}^T,$$

Where $\{j,k,l\}^T$ – is a set of correctly pointed relationships of concepts from the set of relationships $\{\tilde{R}_i\}$. The number of correctly pointed relationships of concepts from the set of relationships $\{\tilde{R}_i\}$ is equal to m_i^T.

Metric 9

The quality metric $\rho_9(c_i,\tilde{c_i})$ is analogous to metric (4) and is defined as a difference between the weighted number of correctly and incorrectly pointed relationships of concepts from the set of relationships $\{\tilde{R}_i\}$:

$$\rho_9(c_i,\tilde{c_i}) = \rho_9(\gamma, c_i,\tilde{c_i}) = \rho_8(c_i,\tilde{c_i}) - \gamma \sum_{j,k,l} v\left(R_{j,k,l}\right), \; (j,k,l) \in \{j,k,l\}^F, \tag{10}$$

Where

$\gamma\epsilon[0,1]$ - the weight coefficient;

in case if $\{j,k,l\}^F$ – is a set of incorrectly pointed relationships of concepts from the set of relationships $\{\tilde{R}_i\}$. The maximum number of indexes in set of incorrectly pointed relationships of concepts from the set of relationships $\{\tilde{R}_i\}$ is equal to m_i^F.

Metric 10

The quality metric $\rho_{10}(c_i,\tilde{c_i})$ is defined as an additive parcel of metrics (7) – (9), that is:

$$\rho_{10}(c_i,\tilde{c_i}) = \rho_{10}(\delta,\gamma, c_i,\tilde{c_i}) = \sum_{j=6}^{9} \lambda_j \rho_j\left(c_i,\tilde{c_i}\right), \tag{10}$$

Where $\lambda_j\epsilon[0,1]$ - the weight coefficient.

The values of the metrics (7) – (10) have different signs and scales. Therefore it is useful to use standardized values of the above mentioned metrics:

$$\tilde{\rho}_j(c_i,\tilde{c}_i) = \frac{\rho_j(c_i,\tilde{c}_i)-\rho_j^{min}(c_i,\tilde{c}_i)}{\rho_j^{max}(c_i,\tilde{c}_i)-\rho_j^{min}(c_i,\tilde{c}_i)} \in [0,1], \quad j \in [7:10] \tag{11}$$

The parameters $\rho_j^{max}(c_i,\tilde{c}_i), \rho_j^{min}(c_i,\tilde{c}_i)$ - the minimum and maximum possible values of metrics (7) – (10) correspondently.

It is easy to see, that

$$\rho_6^{max}(c_i,\tilde{c}_i) = \sum_j \mu\left(c_j\right); \;\; \rho_6^{min}(c_i,\tilde{c}_i) = 0, j \in [1:n_i], j \neq i$$

$$\rho_7^{max}(c_i,\tilde{c}_i) = \rho_6^{max}(c_i,\tilde{c}_i) \;\; ; \;\; \rho_7^{min}(c_i,\tilde{c}_i) = -\delta\rho_6^{max}(c_i,\tilde{c}_i),$$

$$\rho_8^{max}(c_i,\tilde{c}_i) = \sum_{j,k,l} v(R_{j,k,l}), (j,k) \in [1:n_i], j \neq k, l \in [0:r]; \;\; \rho_8^{min}(c_i,\tilde{c}_i) = 0,$$

$$\rho_9^{min}(c_i,\tilde{c}_i) = -\gamma\rho_8^{max}(c_i,\tilde{c}_i); \;\; \rho_9^{max}(c_i,\tilde{c}_i) = \rho_8^{max}(c_i,\tilde{c}_i).$$

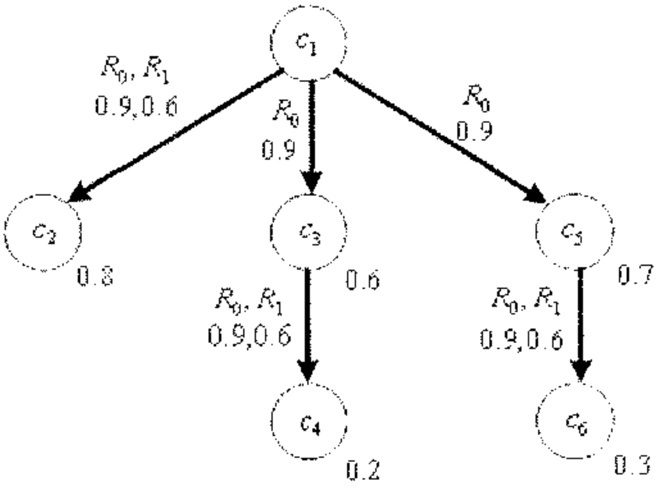
Notes:

1. The sum $\sum_j \mu\left(c_j\right)$ is a common sum of all concepts in the set $\{c_i\}$ excluding the concept c_i.
2. The sum $\sum_{j,k,l} v\left(R_{j,k,l}\right)$ is a common sum of all weights of relationships in the set $\{c_i\}$.

Based on the standardized metrics (7-10) different linear and nonlinear scales for the learning quality estimation could be drawn.

V. *Example*

Let us consider as an example the learning module “The classification of optimization tasks”, which is included into the course “Optimization methods” [9]. In this module there are a set of concepts. One concept c_1 is an output concept of the considerable module as well as four other concepts c_2 , c_3 , c_4 , c_5 are input concepts. We shell define also one more concept c_7 as an output concept. The semantic net is shown at the picture 1.



Picture 1 – Directed multigrapg of the semantic net SS_i

As it is shown at the picture 1, the concepts c_2 and c_6 are connected to concept c_1 in extend means as follows:

$$\{c_i\} = \{c_j, j \in [1:6]\} \text{ and } n_1=6.$$

The computable complexity of the concepts from the set $\{c_1\}$ are the following (shown at the picture 1):

$$\mu_2 = 0.9,\ \mu_3 = 0.6, \mu_4 = 0.2,$$

$$\mu_4 = 0.7,\ \mu_5 = 0.8,\ \mu_6 = 0.3$$

There are relationships between the concepts: R_0 means direct links, R_1 means "a kind of", R_2 means "has a part". The concepts from the set of concepts $\{c_1\}$ connected each other by the following relationships:

- Concept c_1 and concept c_2 connected each other by relationships R_0 and R_1;
- Concept c_1 and concept c_3 connected each other by relationship R_0;
- Concept c_1 and concept c_5 connected each other by relationship R_0;
- Concept c_3 and concept c_4 connected each other by relationship R_0 and R1;
- Concept c_5 and concept c_6 connected each other by relationship R_0 and R1.

So m_1 =8 and

$\{R_{1,2}\}=\{R_{1,2,0}=R_0, R_{1,2,1}=R_1\}$, $\{R_{1,3}\}=\{R_{1,3,0}=R_0\}$, $\{R_{1,5}\}=\{R_{1,5,0}=R_0\}$,

$\{R_{3,4}\}=\{R_{3,4,0}=R_0, R_{3,4,1}=R_1\}$, $\{R_{5,6}\}=\{R_{5,6,0}=R_0, R_{5,6,1}=R_1\}$

The weight of relationships will be correspondently:

$$v(R_0)=0.9,\ v(R_1)=0.6,\ v(R_2)=0.5$$

Therefore we have:

$\{V_{1,2}\}=\{0.9,0.6\}$; $\{V_{1,3}\}=\{0.9\}$; $\{V_{1,5}\}=\{0.9\}$; $\{V_{3,4}\}=\{0.9, 0.6\}$; $\{V_{5,6}\}=\{0.9, 0.6\}$.

Let us that the set of concepts $\{\tilde{c_i}\}$ of the semantic map of the student consists of correct concepts c_2, c_3, c_5 (the concepts from the set $\{c_1\}$) and one incorrect concept c_7, which is not included into the set $\{c_1\}$.

In other words let us that in the cognitive map there are following concepts: $\tilde{c_2} = c_2$, $\tilde{c_3} = c_3$, $\tilde{c_5} = c_5$, $\tilde{c_6} = c_7$, so $n_1 > \tilde{n_1} = 5$. The cortege of the correct concepts is defined as {2,3,5}, but the cortege of incorrectly defined concepts is {4,6}. The set of incorrect indexes $\{j_1\}^F$={4,6}.

Let it be also that the student pointed the following relationships between the concepts:

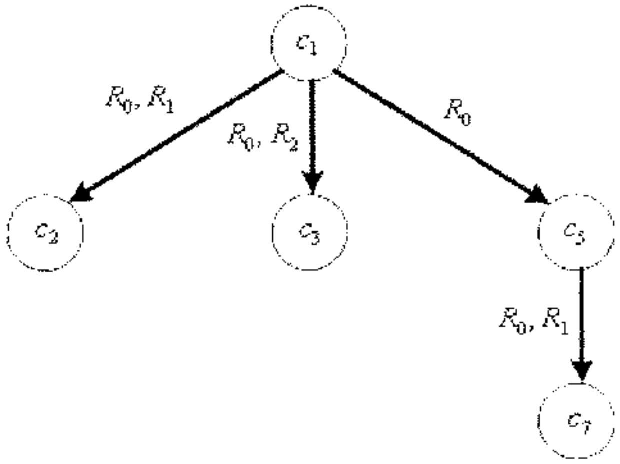
- Concept c_1 and concept c_2 connected each other by relationships R_0 and R_1 (correct);
- Concept c_1 and concept c_3 connected each other by relationship R_0 (correct) and R_2 (incorrect);
- Concept c_1 and concept c_5 connected each other by relationship R_0 (correct);
- Concept c_5 and concept c_7 connected each other by relationship R_0 and R1 (incorrect).

So the cognitive map CM_1 (shown at the picture 2) has the following relationships:

$\{\tilde{R}_{1,2}\}=\{\tilde{R}_{1,2,0}=R_0, \tilde{R}_{1,2,1}=R_1\}$, $\{\tilde{R}_{1,3}\}=\{\tilde{R}_{1,3,0}=R_0, \tilde{R}_{1,3,1}=R_2\}$, $\{\tilde{R}_{1,5}\}=\{\tilde{R}_{1,5,0}=R_0\}$,

$\{\tilde{R}_{5,6}\}=\{\tilde{R}_{5,6,0}=R_0, \tilde{R}_{5,6,1}=R_1\}$ $m_1 > \tilde{m}_1 = 7$.

The cognitive map CM_1 correspondent to the semantic net SS_1, is defined as a weighted directed multi graph without back loops $\tilde{G}_1$.



Picture 2 – The Cognitive map's multi graph

Let us use a quality metric (7) and (9) to estimate the quality of student's learning:

$$\rho_7(c_i,\tilde{c_i})\,, \alpha = \beta = 1$$

$$\rho_9(c_i,\tilde{c_i})\,,\ \delta = \gamma = 1$$

At the first step let us calculate metric (6):

$$\rho_6(c_i,\tilde{c_i}) = 0.9 + 0.6 + 0.7 = 2.2$$

The second step is a metric (7) calculation:

$$\rho_7(c_i,\tilde{c_i}) = \ \rho_6(c_i,\tilde{c_i}) - \delta \sum_j \mu\left(c_{i,j}\right) = 2.2 - (0.2 + 0.3) = 1.7$$

Analogously

$$\rho_8(c_i,\tilde{c_i}) = 0.9 + 0.6 + 0.9 + 0.9 = 3.3$$

$$\rho_9(c_i,\tilde{c_i}) = \ 3.3 - (0.5 + 0.9 + 0.6) = 1.3$$

It is easy to see that

$$\rho_6^{max}(c_i,\tilde{c}_i) = 0.9 + 0.6 + 0.2 + 0.7 + 0.8 + 0.3 = 3.5$$

Therefore

$$\rho_7^{min}(c_i,\tilde{c}_i) = -\rho_6^{max}(c_i,\tilde{c}_i) = -3.5$$

$$\rho_7^{max}(c_i,\tilde{c}_i) = \rho_6^{max}(c_i,\tilde{c}_i) \ \ = 3.5$$

The standardized metric

$$\tilde{\rho}_7\ (c_1,\tilde{c}_1) = \frac{\rho_7(c_1,\tilde{c_1}) - \rho_7^{min}(c_1,\tilde{c}_1)}{\rho_7^{max}(c_i,\tilde{c}_i) - \rho_7^{min}(c_1,\tilde{c}_1)} = \frac{1.7-(-3.5)}{3.5-(-3.5)} \approx 0.74$$

According to 5-marks scale (see table 1) the value of metric (7) corresponds to mark 4.

Analogously for metric (9):

$$\rho_8^{max}(c_1,\tilde{c}_1) = 0.9+0.6+0.9+0.9+0.9+0.6+0.9+0.6 = 6.3$$

$$\rho_9^{min}(c_1,\tilde{c}_1) = -\gamma\rho_8^{max}(c_i,\tilde{c}_i) = -6.3;\ \ \rho_9^{max}(c_i,\tilde{c}_i) = \rho_8^{max}(c_i,\tilde{c}_i) = 6.3$$

According to (11) we could calculate:

$$\tilde{\rho}_9(c_1,\tilde{c}_1) = \frac{\rho_9(c_1,\tilde{c}_1) - \rho_9^{min}(c_1,\tilde{c}_1)}{\rho_9^{max}(c_1,\tilde{c}_1) - \rho_9^{min}(c_1,\tilde{c}_1)} = \frac{1.3-(-6.3)}{6.3-(-6.3)} \approx 0.63 \in [0,1]$$

According to 5-marks scale (see table 1) the value of metric (9) corresponds to mark 4 also.

VI. *Conclusion*

The method of the student conceptual knowledge estimation was proposed in this article. The method could be used in the intellectual learning system, the knowledge dataset of which has semantic network. The formalization of the semantic net was given. The cognitive maps were used in order to describe the student's ideas about learning subject' formalization. The quality of student's comprehension of a proper concept could be estimated by the measure of similarity between the semantic net's graph and cognitive map's graph. A set of metrics were proposed which formalize the similarity of above mentioned graphs. The metrics use concepts' complexity measures and weights of relationships between the concepts. The example has been given to illustrate the proposed method.

VII. *References*

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