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Educational Semantic Networks and their Applications

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Abstract

In this paper the authors presents an algebraic structure about educational semantic networks. The structure could be used to model the content of an electronical course. This structure enables to perform operations to combine more electronical courses and to obtain a new course, to define a pedagogical technique to teach a course, to pursue the evolution of students during the instruction process. The educational semantic networks could be used in the software development in the field of computer assisted instruction and to design software based on pedagogical agent.

Key words: *educational semantic network, algebraic structure, knowledge representation, e-course, e-learning*

Introduction

A semantic network is a graphical notation to knowledge representation in a structure with nodes interconnected by arcs. The nodes are primitives to represent concepts, events, states and the arcs are primitives which abstract the relations between nodes. The first implementation of semantic networks in computer systems was developed in the artificial intelligence field and translation machines. The roles of the semantic networks in the education process were stressed by Jonassen [1].

The human memory is organized according to the relations existing between ideas, so structuring the information according to semantic networks allows an active instruction process.

The semantic networks provide an efficient mode to navigate in an electronic course. The semantic networks force the teacher to organize the pedagogical materials in a logical mode, so that the students can understand better the educational materials. The new concepts of the course will be integrated in an existing conceptual structure.

To use the educational semantic networks in the e-learning software, the author proposes some definitions about educational semantic networks [2], operations with them and an algebraic structure.

Problem Formulation

Definition. We call an educational semantic network, noted R , a knowledge representation in the form:

$$R = \{\{N_1, N_2, \dots, N_k\}, \{L_1, L_2, \dots, L_k\}, \{C_1, C_2, \dots, C_k\}, \{i \to j(L) \mid i, j = \overline{1,k}\}\},$$

where N_i are nodes labeled with L_i and these nodes has attached educational resources in multimedia format noted with C_i and $\{i \to j(L)\}$ represents a relation from node i to node j labeled with L .

Definition. The educational semantic network with a single node is called the singular educational semantic network and it is presented in the form:

$$R = \{\{N_1\}, \{L_1\}, \{C_1\}, \varnothing\}.$$

Definition. We call an empty semantic network the semantic network without any node or relation.

The Operations with Educational Semantic Networks

The reunion of two educational semantic networks, noted $R_1 \oplus R_2$ is defined in this way [3]:

Case no. 1 The two semantic networks, R_1 and R_2, have in common at least one node.

Let consider:

$$R_1 = \{\{N_1, N_2, \dots, N_k\}, \{L_1, L_2, \dots, L_k\}, \{C_1, C_2, \dots, C_k\}, \{i \to j(L) \mid i, j = \overline{1,k}\}\},$$

$$R_2 = \{\{N_k, N_{k+1}, \dots, N_p\}, \{L_k, L_{k+1}, \dots, L_p\}, \{C_k, C_{k+1}, \dots, C_p\}, \{i \to j(L) \mid i, j = \overline{k,p}\}\},$$

where node N_k is a common node.

$$R_1 \oplus R_2 = \{\{N_1, N_2, \dots, N_k\} \cup \{N_k, N_{k+1}, \dots, N_p\}, \{L_1, L_2, \dots, L_k\} \cup \{L_k, L_{k+1}, \dots, L_p\}, \{C_1, C_2, \dots, C_k\} \cup \{C_k, C_{k+1}, ..., c_p\}, \{i \to j(L) \mid i, j = \overline{1,k}\} \vee \{i \to j(L) \mid i, j = \overline{k,p}\}\}.$$

Example:

Let consider two educational semantic networks with one node in common. The reunion of them is presented in the figure no. 1.

Case no. 2. The two semantic networks, R_1 and R_2, have not any node in common.

$$R_1 = \{\{N_1, N_2, \dots, N_k\}, \{L_1, L_2, \dots, L_k\}, \{C_1, C_2, \dots, C_k\}, \{i \to j(L) \mid i, j = \overline{1,k}\}\}$$

$$R_2 = \{\{N_{k+1}, N_{k+2}, \dots, N_p\}, \{L_{k+1}, L_{k+2}, \dots, L_p\}, \{C_{k+1}, C_{k+2}, \dots, C_p\}, \{i \to j(L) \mid i, j = \overline{k+1,p}\}\}$$

$$R_1 \oplus R_2 = \{\{N_1, N_2, \dots, N_k\} \cup \{N_{k+1}, N_{k+2}, \dots, N_p\}, \{L_1, L_2, \dots, L_k\} \cup \{L_{k+1}, L_{k+2}, \dots, L_p\}, \{C_1, C_2, \dots, C_k\} \cup \{C_{k+1}, C_{k+2}, ..., c_p\}, \{i \to j(L) \mid i, j = \overline{1,k}\} \vee \{i \to j(L) \mid i, j = \overline{k+1,p}\} \vee \{New(i \to j(L))\}\}$$

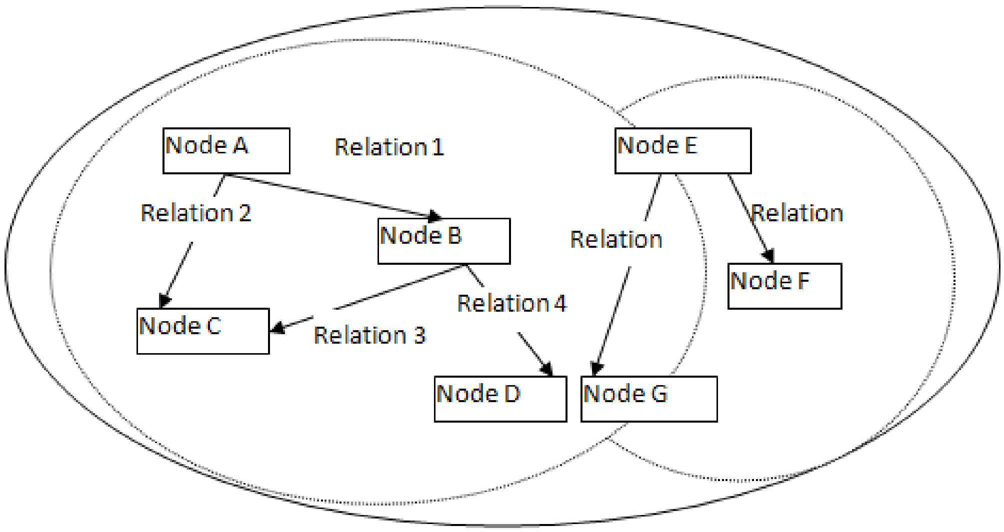

Fig. 1. The reunion of two educational semantic network with one common node

The reunion could be realized if and only if we can draw a relation between two nodes from each network.

Remark. In an educational semantic network isolated nodes don't exist.

Example:

Let consider two educational semantic networks without any node in common. The reunion of them is presented in the figure no. 2.

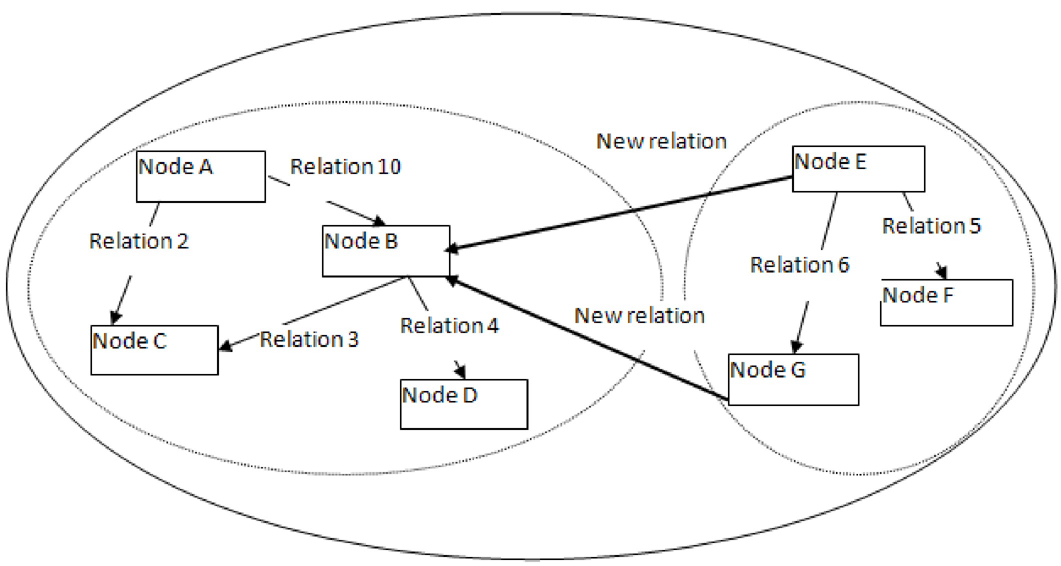

Fig. 2. The reunion of two educational semantic network without any common node

Remark. A concept could be added to a network using the reunion operation between a network and a single network.

The intersection of two educational semantic networks is a semantic network, noted $R_1 \otimes R_2$ defined in this way [3]:

The two semantic networks R_1 and R_2 have at least one common node.

Let consider:

$$R_1 = \{\{N_1, N_2, \ldots, N_k\}, \{L_1, L_2, \ldots, L_k\}, \{C_1, C_2, \ldots, C_k\}, \{i \to j(L) \mid i, j = \overline{1,k}\}\},$$

$$R_2 = \{\{M_1, M_2, \ldots, M_p\}, \{E_1, E_2, \ldots, E_p\}, \{T_1, T_2, \ldots, T_p\}, \{i \to j(L) \mid i, j = \overline{1,p}\}\},$$

$$\begin{aligned} R_1 \otimes R_2 = \{&\{N_1, N_2, \ldots, N_k\} \cap \{M_1, M_2, \ldots, M_p\}, \{L_1, L_2, \ldots, L_k\} \cap \{E_1, E_2, \ldots, E_p\}, \\ &\{C_1, C_2, \ldots, C_k\} \cap \{T_1, T_2, \ldots, T_p\}, \\ &\{i \to j(L), 1 \le i, j \le card(\{N_1, N_2, \ldots, N_k\} \cap \{M_1, M_2, \ldots, M_p\}) \wedge \\ &\to j(L) \in R_1 \wedge i \to j(L) \in R_2\}\} \end{aligned}.$$

Remark. The result of the intersection of two educational semantic networks without any common node is the empty network.

The difference between two educational semantic networks is a semantic network, noted $R_1 - R_2$:

$$R_1 = \{\{N_1, N_2, \ldots, N_k\}, \{L_1, L_2, \ldots, L_k\}, \{C_1, C_2, \ldots, C_k\}, \{i \to j(L) \mid i, j = \overline{1,k}\}\},$$

$$R_2 = \{\{M_1, M_2, \ldots, M_p\}, \{E_1, E_2, \ldots, E_p\}, \{T_1, T_2, \ldots, T_p\}, \{i \to j(L) \mid i, j = \overline{1,p}\}\},$$

$$\begin{aligned} R_1 - R_2 = \{&\{N_1, N_2, \ldots, N_k\} - \{M_1, M_2, \ldots, M_p\}, \{L_1, L_2, \ldots, L_k\} - \{E_1, E_2, \ldots, E_p\}, \\ &\{C_1, C_2, \ldots, C_k\} - \{T_1, T_2, \ldots, T_p\}, \\ &\{i \to j(L), 1 \le i, j \le card(\{N_1, N_2, \ldots, N_k\} - \{M_1, M_2, \ldots, M_p\}) \wedge \\ &i \to j(L) \in R_1 \wedge i \to j(L) \notin R_2\}\} \end{aligned}.$$

Example:

Let consider two educational semantic networks. The difference between the two educational semantic networks is presented in the figure no. 3.

The selection of an educational semantic network after a set of nodes looks like that [3]:

Let consider a semantic network

$$R_1 = \{\{N_1, N_2, \ldots, N_k\}, \{L_1, L_2, \ldots, L_k\}, \{C_1, C_2, \ldots, C_k\}, \{i \to j(L) \mid i, j = \overline{1,k}\}\}$$

and a set of nodes $N = \{N_{i1}, N_{i2}, \ldots, N_{ip}\}$.

$$\begin{aligned} SEL_N R_1 = \{&\{N_{i1}, N_{i2}, \ldots, N_{ip}\}, \{L_{i1}, L_{i2}, \ldots, L_{ip}\}, \{C_{i1}, C_{i2}, \ldots, C_{ip}\}, \\ &\{i \to j(L) \mid i, j = \overline{i1, ip}\}\} \end{aligned}$$

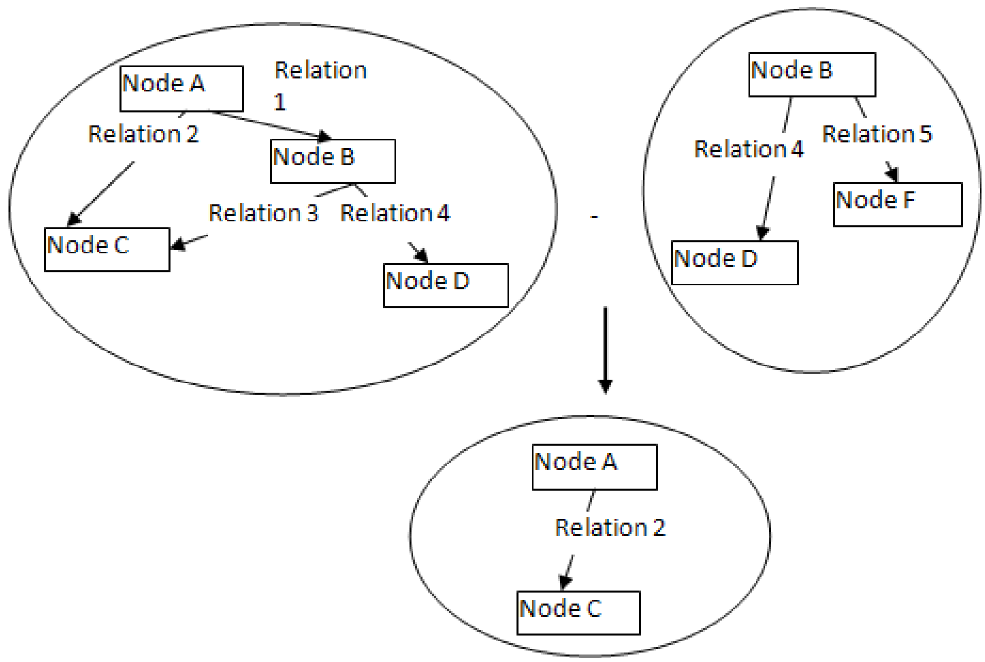

Fig. 3. The difference between two educational semantic network

Example: The selection operation is presented in the figure no. 4. The set of nodes is $\{N_A, N_B, N_D\}$.

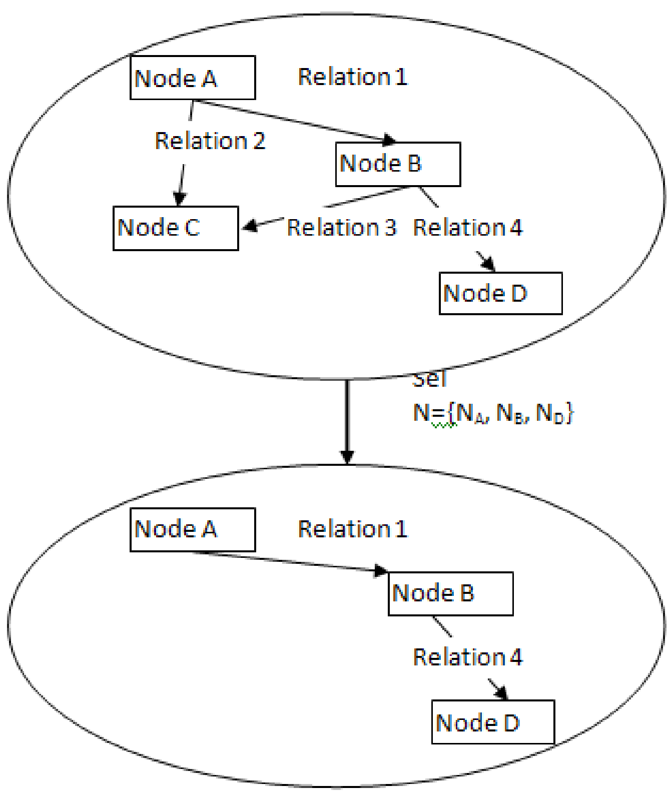

Fig. 4. The selection of an educational semantic network after a set of nodes

The Monoid of Educational Semantic Networks

Proposition. We note with $\Re$ the set of all educational semantic networks. $\Re$ is a monoid considering the reunion operation.

$$\Re \times \Re \to \Re, (R_1, R_2) \to R_1 \oplus R_2$$

$$\Re \times \Re \to \Re, (R_1, R_2) \to R_1 \otimes R_2$$

Proof. To proof that the set of all educational semantic networks is a monoid, we have to proof that the operations of reunion is associative and the empty semantic network is an identity element.

1. Let's consider the reunion operation.

$$(R_1 \oplus R_2) \oplus R_3 = R_1 \oplus (R_2 \oplus R_3)$$

The property is evidence while the reunion of the sets of objects is associative.

2. The empty educational semantic network is the identity element for reunion operation.

$$E = \{\{\varnothing\}, \{\varnothing\}, \{\varnothing\}, \varnothing\}$$

$$E \oplus R = R \oplus E = R$$

This monoid is a commutative monoid while the reunion operation is commutative.

$$R_1 \oplus R_2 = R_2 \oplus R_1$$

Definition. Let's consider R an educational semantic network.

$$R = \{\{N_1, N_2, \ldots, N_k\}, \{L_1, L_2, \ldots, L_k\}, \{C_1, C_2, \ldots, C_k\}, \{i \to j(L) \mid i, j = \overline{1,k}\}\}.$$

We call the set of parts of R and we noted with $\mathrm{P}(R)$:

$$\mathrm{P}(R) = \{\mathrm{P}(\{N_1, N_2, \ldots, N_k\}), \mathrm{P}(\{L_1, L_2, \ldots, L_k\}), \mathrm{P}(\{C_1, C_2, \ldots, C_k\}), \mathrm{P}(\{i \to j(L) \mid i, j = \overline{1,k}\})\}$$

Proposition. Let's consider R an educational semantic network and $\mathrm{P}(R)$ the set of parts. The following properties are true:

1. $(R_1 \oplus R_2) \oplus R_3 = R_1 \oplus (R_2 \oplus R_3),\ \forall R_1, R_2, R_3 \in \mathrm{P}(E)$;
2. $E \oplus R = R \oplus E = R,\ \forall R \in \mathrm{P}(E)$;
3. $R_1 \oplus R_2 = R_2 \oplus R_1,\ \forall R_1, R_2 \in \mathrm{P}(E)$.

$(\mathrm{P}(E), \oplus)$ is a commutative monoid.

Analog, $(\mathrm{P}(E), \otimes)$ is a commutative monoid, where the identity element is R.

Application

Modelling e-Courses

The educational semantic networks can be used to model the e-courses.

Consider a course C. The course has $O_1, O_2, \ldots, O_n$, n instructional objectives. For each objective, we could build an educational semantic network.

$$O_k \rightarrow R^k$$

$$R^k = \left\{\left\{N_1^k, N_2^k, \ldots, N_p^k\right\}, \left\{L_1^k, L_2^k, \ldots, L_p^k\right\}, \left\{C_1^k, C_2^k, \ldots, C_p^k\right\}, \left\{i \rightarrow j(L), i, j = \overline{1, p}\right\}\right\},$$

where N_i^k are labeled nodes (L_i^k) and each node is associated with a pedagogical resource called content C_i^k.

$i \rightarrow j(L)$j means a relation from node i to node j labeled with L.

The educational semantic network associated to the course is obtained using the reunion operation R^k, $\overline{k = 1, n}$.

$$C \rightarrow R$$

$$R = R^1 \oplus R^2 \oplus \ldots \oplus R^k$$

Modeling the "Object Oriented Programming"Course

To build the e-course with title "Object Oriented Programming", we could use a set of educational semantic network. Some of them are presented in the following figures.

$R^1 =$

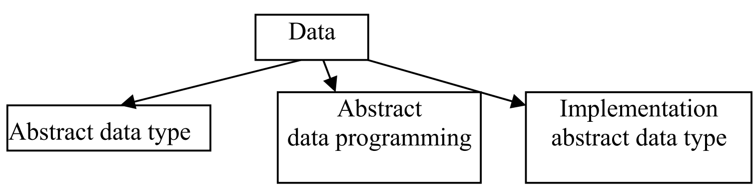

Fig. 5. The educational semantic network for the objective "data"

$R^2 =$

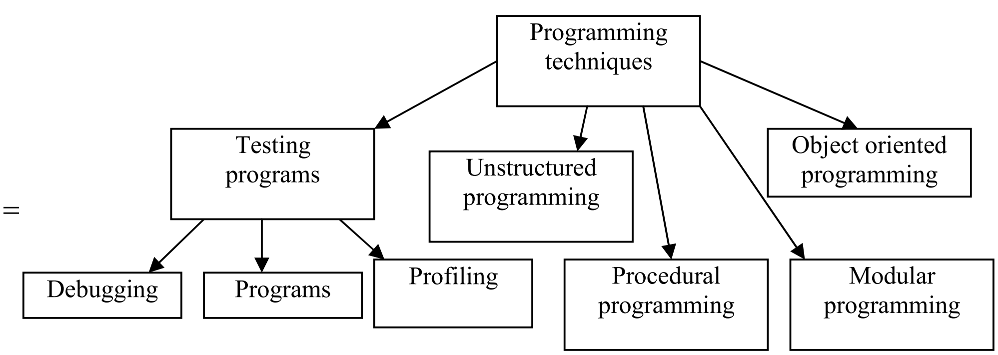

Fig. 5. The educational semantic network for the objective "programming techniques"

$R^3 =$

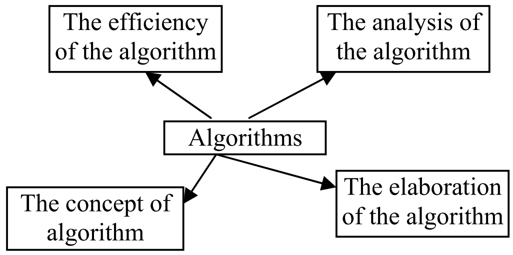

Fig. 6. The educational semantic network for the objective "algorithm"

$R^4 =$

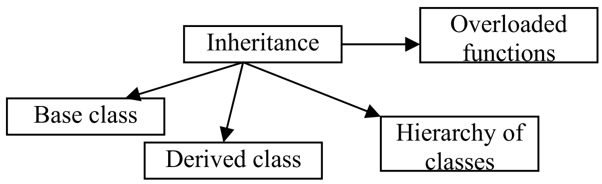

Fig. 7. The educational semantic network for the objective "inheritance"

$R^5 =$

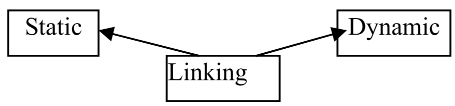

Fig. 8. The educational semantic network for the objective "linking"

$R^6 =$

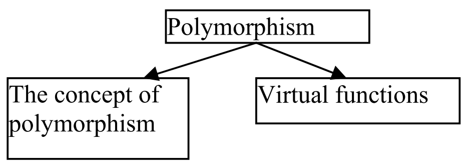

Fig. 9. The educational semantic network for the objective "polymorphism"

$R^7 =$

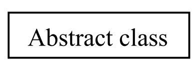

Fig. 10. The educational semantic network for the objective "abstract class"

$R^8 =$

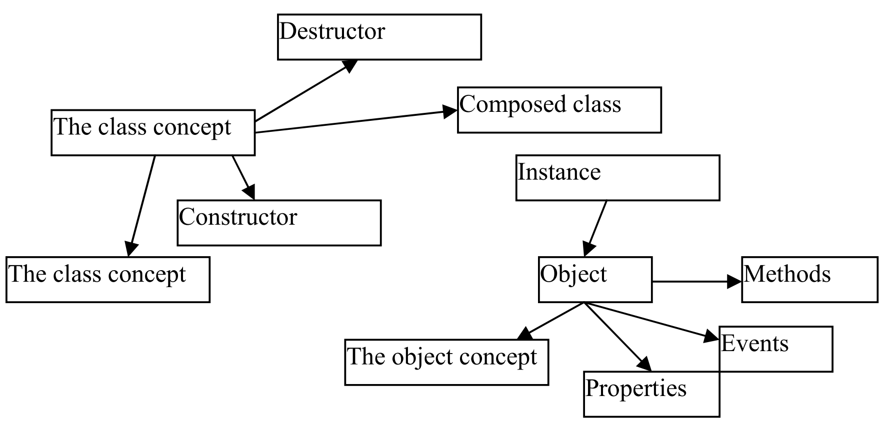

Fig. 11. The educational semantic network for the objective "class, object"

The semantic network could be stored in the computer using databases. Each node has attached more files representing the educational resources in the multimedia format. Applying the reunion operation, results the educational semantic network of the course “Object Oriented Programming”.

$$R = R^1 \oplus R^2 \oplus R^3 \oplus R^4 \oplus R^5 \oplus R^6 \oplus R^7 \oplus R^8$$

To teach only the module with title “Testing programs”, we have to apply the selection operator to R^2 semantic network after the node with the same title.

The advantages of using this kind of structure for the pedagogical resources are [4]:

1. E-courses could be managed more easy;
2. the possibility of building new courses based on the existing courses;
3. possibility of using teaching and learning strategies, especially according to the profile learning of each student.

Conclusions

The evolution of information technologies enables to teach according to a variety of the instruction strategies. The great majority of the software programs dedicated to computer assisted instruction present the pedagogical resources in one format. So, the students regardless of the learning style of them have to learn in the same way. The structure presented in the paper is a base structure for the e-courses. The structure was used in the software system development based on pedagogical agent, presented in PhD thesis and confirms that students learn better if the teachers use a strategy based on learning styles [5, 6].

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Rețele semantice educaționale şi aplicațiile lor

Rezumat

În acest articol autorii prezintă structura algebrică a rețelelor semantice educaționale. Structura propusă în lucrare poate fi utilizată pentru modelarea conținuturilor cursurilor electronic: permite operații de generare de noi cursuri electronice, definirea de tehnici pedagogice pentru predarea cursurilor, tehnici de evaluare a studenților.