Scientific article DOI:10.18287/2223-9537-2023-13-1-99-112

Designing an ontology of the e-learning course content

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Abstract

Knowledge modeling, closely related to ontologies, is an important semantic technology and research area. The article deals with the e-learning course content model concept. The content model is based on structuring the content into separate fragments, called learning elements. These learning elements integrate into a tree directed graph. The content model is defined as a combination of such a graph and a table of attributes of educational elements with requirements for didactic indicators of their study. The rules for building models of the electronic educational content are formulated. The mathematical properties of these models are discussed and their integral characteristics are introduced. The proposed approach to content modeling is in line with the SCORM specifications for international e-learning, complements them with targets, didactic design algorithms and analysis of educational materials. Formation algorithms and methods of presenting the content model make it possible to automate the process of its construction and didactic analysis in the form of a visual interactive dialogue between developers of electronic educational resources in instrumental author's environments.

Key words: *e-learning, electronic educational resources, structuring of educational material, content model, tree-oriented graphs, SCORM.*

For citation: *Solovov A.V., Menshikova A.A.* Designing an ontology of the e-learning course content. *Ontology of designing*. 2023; 13(1): 99-112. DOI:10.18287/2223-9537-2023-13-1-99-112.

Conflict of interest: The authors declare no conflict of interest.

Introduction

In the past few years, knowledge modeling, closely related to ontologies, has been an important semantic technology and research area [1]. However, "while ontologies have become the de facto standard in the field of knowledge base development, the processes of extracting and especially structuring knowledge still remain a kind of "blank spot" in the modern literature on knowledge engineering" [2, p.88].

Structuring knowledge is essential in learning. It is the structural "dissection" of knowledge for their presentation in the framework of lectures, in various types of textbooks (printed or electronic) that has always been and continues to be one of the main functions of the teacher. Structuring of educational material can be defined as the process of organizing information to improve its understanding and memorization. As a result of this process, fragments of the studied material are connected in meaning into an integral group or several such groups.

The design of e-learning also begins with the structuring of educational material. There are different, including ontological approaches to the formalization of this process. In the work [3] as a formal basis for individualized e-learning, it is proposed to use semantic models that include the apparatus of vector representations of knowledge graphs, which has the flexibility and expressiveness of the ontological approach. Modeling of e-learning processes using directed graphs is offered in the work [4]. The article [5] presents a formal description of the structural-hierarchical didactic model of e-learning. A distinctive feature of this model is the support for dividing educational objects into didactic components. The book [6] proposes the concept of electronic educational resources integrated into a multimedia system open for development.

The development of the problems of e-learning makes it possible to transfer the educational process to the industrial "rails", to introduce specialization and division of labor into it. Industrialization entails the unification and standardization of various educational procedures. The most famous are the standards of international organizations AICC [7], IMS [8], ADL [9]. An overview of the various standards is given in [10, 11].

The basis of international unified procedures for structuring educational materials since the late 90s are the SCORM (The Sharable Content Object Reference Model) specifications [12] and its development in the xAPI (Tin Can) and cmi5 specifications [13]. One of the basic ideas of SCORM is the compilation of electronic educational resources from blocks of educational material, called Sharable Content Objects (SCOs). Such objects may include semantically local text fragments, graphic illustrations, computer programs, video clips, any other typical elements of hypermedia or their combinations.

SCORM does not impose restrictions on the size of SCOs and contact training time with them. At the same time, it is assumed that the object represents a relatively small part of the content of the studied educational material. The content developer should determine the size of the SCO based, first, on the amount of information needed to achieve the learning outcome, and second, on the degree of multiple use that the developer wants to obtain.

Various SCOs are placed in network depositories (corporate or global), which provides access to them to users of these networks. Developers of training materials, using metadata about SCOs, find suitable objects and arrange from various SCOs their aggregation in the form of electronic textbooks, computer courses, etc. The developer does not always copy the selected SCOs. You can specify only their network URLs. The collected aggregation is hosted in a Learning Management System (LMS) that supports the SCORM specifications. Any such LMS can run and execute SCOs, regardless of the technology platform on which these learning objects were created.

However, the SCORM specifications do not contain specific structuring techniques and models, making them difficult to apply in practice. The Russian School of Didactics has advanced research experience in the field of structuring educational materials. The most famous in this regard are the didactic developments of V.P. Bespalko [14] and E.L. Belkin [15]. In our research, these developments have been adapted and developed in relation to the design of electronic educational resources (EER) [16]. The models for structuring training materials proposed in the works [14-16] are adequate to the basic concepts of SCORM and complement them in terms of didactic goal-setting of SCOs. However, these models do not have a mathematical justification, and the methodology for their construction is focused on the usual, non-automated procedures for designing educational material.

The purpose of this research is to provide a mathematical justification for structuring models [14-16], to investigate the properties and introduce integral characteristics of these models, allowing for didactic analysis and construction of automated procedures for designing the structure of educational material. The research is based on methods of system analysis, discrete mathematics, pedagogical psychology and didactics, many years of experience of the authors in the field of education, theory and technologies of e-learning.

1 Content model

In accordance with [16], the educational material planned for study is divided into separate learning elements (LE). LE is understood as objects, phenomena, concepts, methods of activity selected from the relevant science and included in the curriculum of the academic discipline or section of the academic discipline for their study. The set of LE is presented in the form of a structural scheme, which is called the content graph (CG) of the educational material. The nodes (vertices) of the graph are LE, the edges are hierarchical connections between them. Note that the concept of LE and the presentation of the structure of the educational material in the form of CG are equivalent to the concept of SCOs and their aggregations in SCORM.

In parallel with the construction of the CG, the LE attribute specification (table) is compiled, in which the LE names are entered. An analogue of this process is the compilation of the table of contents of the textbook, when its content is preliminarily divided into sections, subsections or chapters and paragraphs. However, when constructing CG educational material, unlike compiling a table of contents, there is no need to care about the sequence of presentation of LE. It is important to display only the hierarchical structure of the educational material. After structuring and selecting the content of the educational material for each LE, didactic requirements are formulated for the level of assimilation α ($\alpha \in 0,1,2,3,4$), the level of presentation β ($\beta \in 1,2,3,4$) and the level of awareness γ ($\gamma \in 1,2,3$) of the educational material, which are included in the specification of the LE [16, p.12]. At the same time, for each indicator, one or two columns of the LE table are filled.

In the first column, which is not always included in the specification, the "starting" value of the indicator (the estimated level before training) is indicated, in the second column, which is mandatory for inclusion in the specification, the "finish" value of the indicator (the required level after training). Note that the first versions of SCORM (SCORM-2) did not contain such elements of didactic goal-setting. In the latest version (SCORM-4), this gap was partially filled by the inclusion in the characteristics of SCOs of didactic goals based on the taxonomy of the Bloom-Anderson level of knowledge [17].

The totality of the CG and the specification of the attributes of the LE is called the model of the content of the educational material of the EER [16]. As an illustrative example, this article discusses the content model prepared for a fragment of educational material on the theory of orgraphs from the book [18] (Figure 1). Here, in the specification of the attributes of the LE, approximate didactic requirements for the level of knowledge of students of a technical university studying a course of discrete mathematics are indicated.

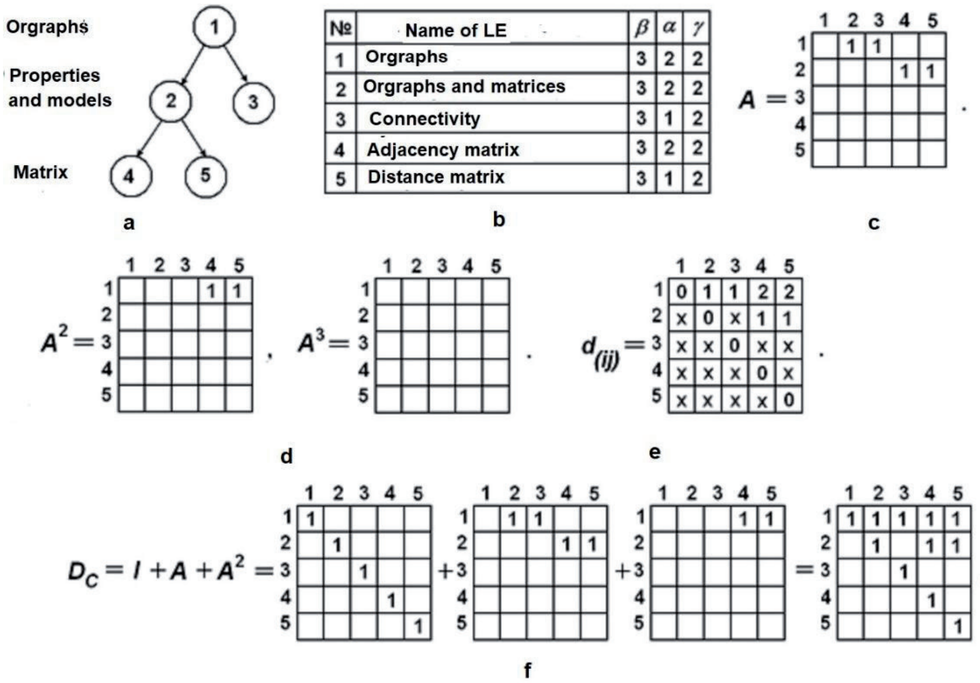


Figure 1 – Example of a content model:
a – content graph; b – specification of LE attributes; c – the matrix of adjacency of CG;
d – the degree of the adjacency matrix CG; e – the distance matrix of the CG; f – CG achievability matrix

2 Definition and rules for constructing a content graph

We will represent the CG as a oriented graph of the tree structure $D = (V, Y)$, where V is the finite set of n vertices (the set of LE), and Y is the finite set m of the oriented edges (hierarchical connections between the LE) of the orgraph. When constructing the CG, we will observe the following rules (see Figure 1, a):

1) the graph has the form of an inverted tree with one root vertex - one LE corresponding to the name of the topic being structured;
2) communication (orientation of the edges) is carried out only in the direction from the root (from top to bottom);
3) there are no separate (hanging) vertices to which there is no connection (arc) from the higher LE, except for the root;
4) only one arc from higher LE can approach a lower LE in the hierarchy;
5) higher LE should be associated with at least two lower LE, otherwise the lower LE is included in the higher LE;
6) grouping of LE at the same level is carried out on any common basis (general basis);
7) the numbering of the vertices of the CG begins at the root and continues sequentially along the levels of grouping of the LE from top to bottom and from left to right. Sometimes it is convenient to number the vertices of the CG in the same way as the table of contents of printed materials. Then the root vertex of the CG is assigned the number 0, the vertices of the first level - 1,2,3, ..., the vertices of the second level - 1.1,1.2,1.3,....2.1,2.2,2.3 ... etc.

We will also assume that the content of lower LE is not a simple decomposition (fragmentation) of the content of the associated higher LE. In particular, the content of lower LE can detail, disclose the individual components of the content of the associated higher LE. Conversely, the content of the higher LE, although it integrates the content of the associated lower LE, is not a simple unification of them.

The mathematical model of CG is its adjacency matrix A (see Figure 1, c). When it is filled, the rows and columns of the matrix are put in accordance with the LE numbers, which are located on the left and top of the matrix. The cells in this matrix can contain zeros or ones. Zero means that there is no hierarchical relationship between the LE specified in the row number and the LE specified in the column number (there is no edge in the CG). Zeros, as a rule, are not put, since the matrix of adjacency of the CG is usually weakly filled. One is placed in the cell of the matrix when there is a hierarchical relationship between the LE. For example, the units in cells 1-3 and 2-5 indicate the presence of corresponding edges in the CG between LE 1 and LE 3, between the LE 2 and the LE 5 (see Figure 1, c).

3 Content graph properties

Property 1. The number of CG arcs is one less than the number of its vertices, m=n-1, with n≥1 and n≠2.

The CG can be constructed by starting with the root vertex and sequentially adding typical fragments in the form of one vertex and an arc entering it (Figure 2). It follows that the number of arcs of the CG will be one less than the number of its vertices. An exception is the case of n=2, in which the CG cannot be constructed, since according to Rule 5 of the CG construc-

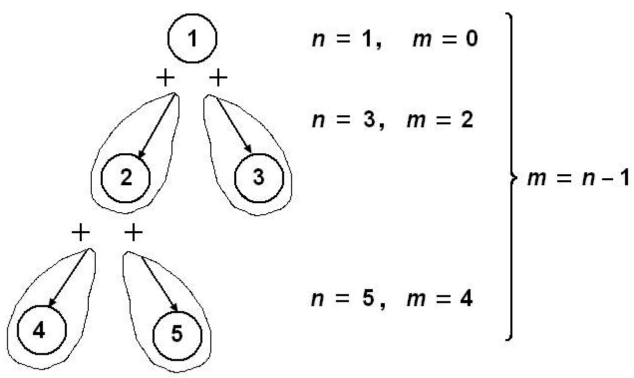


Figure 2 – To property 1 of the content graph

tion, the higher LE must be associated with at least two lower LE.

Property 2. The columns of the vertex adjacency matrix CG $A=(a_{ij})$ contain only one unit except for the column corresponding to the root vertex, which contains only zeros. This property is determined by the fact that, according to the rules of construction of CG 3-4, there is only one incoming arc in any vertex of the CG, except the root (see Figure 1, c).

Property 3. For CG with an adjacency matrix $A=(a_{ij})$, the element $a_{ij}^{(t)}$ in the matrix A^t, where t is the power, may be 0 or 1. The unit defines a single simple (without repeating vertices) path from vertex v_i to vertex v_j of length t.

If t=1, then the result is obvious – the adjacency matrix A indicates the presence of single-length paths (see Figure 1, c). Let be t=2. To go from vertex v_i to v_j in two steps, you need to go from v_i to some vertex v_k in one step and then from v_k to v_j in the next step. The transition from v_i to v_k is determined by the coefficient a_{ik} of the matrix A, the transition from v_k to v_j is determined by the coefficient a_{kj}. The transition from v_i to v_j via v_k is determined by the sum of $\sum_{k=1}^{n} a_{ik}\, a_{kj}$.

This sum is the coefficient $a_{ij}^{(2)}$ of the matrix A^2. From property 2 of the CG (see above) it follows that in column k of coefficients a_{ik} and in column j of coefficients a_{kj}, only one coefficient can be equal to one, and the remaining coefficients are zero. Therefore, each column j of the matrix A^2 can be either completely zero or contain one unit, i.e. the path from v_i to v_j, if any, is the only and simple. By making similar reasoning, it is possible to show the validity of this property for A^3, etc. for A^t (see Figure 1, d).

Property 4. All paths in the CG are simple (with no repeating vertices). According to property 3, each column of the matrix A^t can either be completely zero or contain one unit, i.e. the path from any vertex v_i to another vertex v_j, if any, is the only and simple (without repeating vertices).

Property 5. Let the CG have an adjacency matrix A and a distance matrix (d_{ij}). Then, if the value d_{ij} ($i \neq j$) is defined, then it is equal to t, for which the coefficient $a_{ij}^{(t)}$ in A^t is 1. For $i=j$ $d_{ii}=0$.

The proof follows from property 3 (see above), according to which the coefficients of the matrix A^t indicate all simple paths of length t in CG. Zeros on the principal diagonal of the matrix (d_{ij}) determine the path length of the corresponding vertex to itself (see Figure 1, d, e).

Property 6. Any vertex of the CG is reachable from its root, and to each vertex there is a single and simple path from the root.

Let's start moving from any vertex towards the root in the direction opposite to the orientation of the edges. On this path, there will be only one possible direction in each branch (vertex) of the orgraph, since any vertex of the CG, except for the root vertex, has only one incoming edge. Given that the CG has no higher hanging vertices other than the root, such an advance will have only one trajectory necessarily leading to the root, and therefore, conversely, from the root to any vertex there is necessarily a single and simple path, i.e. all vertices are reachable from the root. Note that any vertex is considered a path, so the root top is achievable for itself.

Property 7. The achievability matrix D_c of the CG is determined through its adjacency matrix A by the formula

$$D_c = I + A + A^2 + \dots + A^{(n-1)/2}. \quad (1)$$

The first term of this formula, unit matrix I, determines the fact that each vertex of the CG is achievable for itself. The subsequent terms indicate all possible paths in the CG of length 1, 2, ..., $(n$-1)/2, the units in the columns of the matrices A, A^2, …, $A^{(n-1)/2}$ indicating these paths are at different positions and do not coincide. The last term corresponds to the longest (potentially) simple path to the CG. Its length is $m/2 = (n-1)/2$, since according to rule 5 of the CG construction, the higher vertex must be adjacent to at least two lower vertices. Consequently, the summation result of formula (1) indicates all simple paths in the CG and thus determines the achievability matrix (see Figure 1, f).

Property 8. Any two vertices of the CG are connected.

The proof follows from the consideration that from any vertex of the CG there is a simple halfway to the root, and from the root any vertex of the CG is achievable. Therefore, any two vertices of the CG are connected at least through the root.

Property 9. The CG is a weakly connected (weak) orgraph with a degree (category) of connectivity equal to 1.

This property is defined by the fact that any pair of CG vertices is conjugated (see property 8), but has neither the properties of a strongly connected orgraph (i.e., the two-way reachability of all vertices) nor a one-way connected orgraph (i.e., the one-way reachability of all vertices) [18].

4 Integral characteristics of the content model

Let's introduce some characteristics that allow you to analyze the structure of educational materials.

1) ***Number of learning elements n.*** This characteristic determines the number of vertices of the CG and characterizes, in a certain, but, of course, not fully the amount of educational material. The value of $n \geq 1$ and $n \neq 2$ (see property 1 CG).

2) ***The number of levels (bases) of structuring U.*** The value of U shows the number of levels (the depth of structuring of the educational material), the degree of hierarchical nesting of some educational elements into others. It is defined by the following two theorems.

Theorem 1. For CG with adjacency matrix A, the exponent of degree t in the series of matrices A, A^2, …, A^t, A^{t+1}, … determines the number of levels of structuring U if there are at least two ones in addition to zeros among the A^t coefficients, and in the A^{t+1} matrix all coefficients are zero.

Proof. In accordance with CG property 3 (see above), the exponent of the t in the matrix A^t determines the presence in the CG of paths of length t, and this length corresponds to the longest tracks. All paths to the CG are simple (see CG property 4) and only the lower level of the CG structure can be moved from any vertex. Therefore, the magnitude of the longest path t is equal to the number of levels of structuring U. At the last level of structuring, there must be at least two vertices (which corresponds to two units in the matrix A^t), since according to rule 5 of the construction of the CG, the higher vertex must be adjacent to at least two lower vertices.

Theorem 2. The maximum possible depth of structuring of the CG of the *Umax* training material depends on the number of LE n ($n \geq 1$, $n \neq 2$) and is determined by the following ratios:

$Umax = (n-1)/2$ *for odd* $n = 1, 3, 5, 7, \dots$; (2)

$Umax = (n-2)/2$ *for even* $n = 4, 6, 8, \dots$. (3)

Proof. The increment n from 1 or from 4 in steps 2 gives the maximum increment of U per unit if the structuring is performed according to the schemes shown in Figure 3. Summarizing these schemes, we get expressions (2, 3). The value of n=2 is excluded from consideration in accordance with rule 5 of the construction of the CG.

3) ***Relative depth of structuring of educational material***

$\overline{U} = U/U_{max}$. (4)

It is always useful to determine the value $\overline{U}$ and its proximity to a limit value equal to one to assess the use of the potential of hierarchical structuring. Thus, for the above example of CG (see Figure 1, a) U=Umax=2, and $\overline{U}$=1, which means the maximum possible degree of hierarchical structuring.

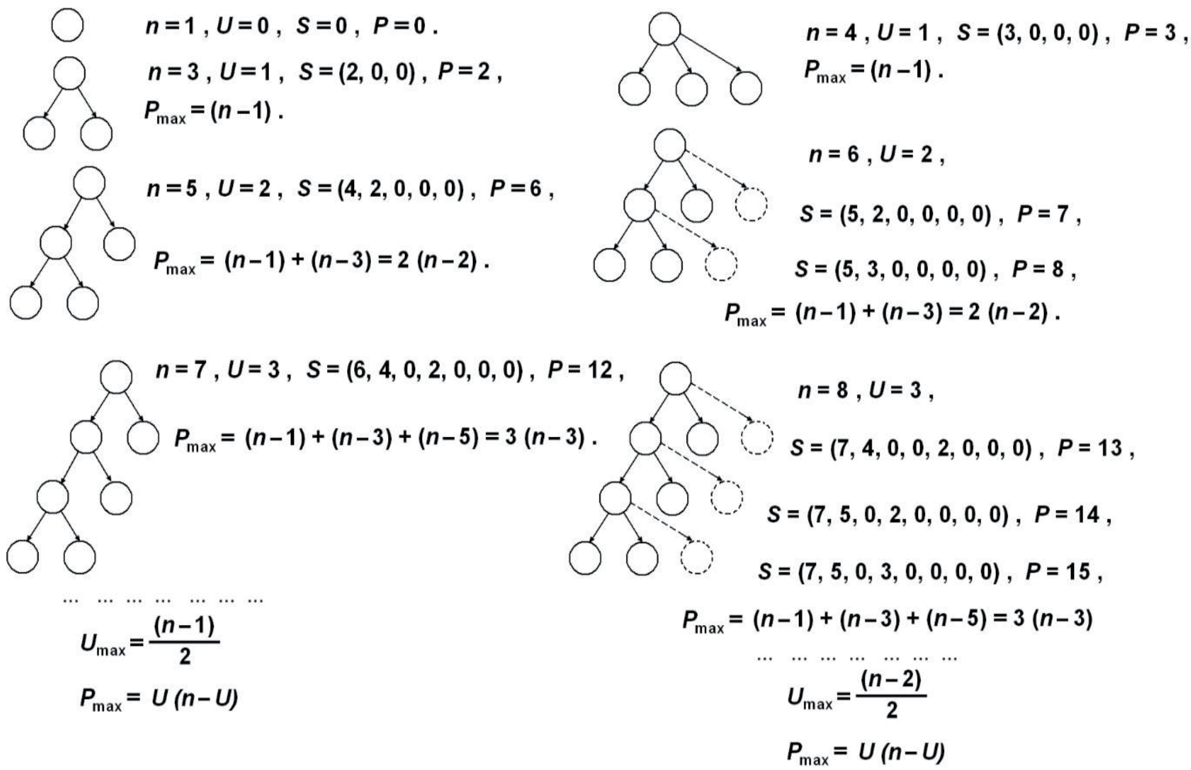


Figure 3 – To theorems 2 and 3

4) ***Vector of structuring of educational material***

$S = (D_c - I)E,$ (5)

Where is D_c – achievability matrix; I – unit matrix; E – column vector of n units.

Vector S allows you to assess the degree of structuring of all LE. Each S_i coefficient of the vector S determines the scalar value - the degree of structuring of the LE with the number i (i.e., the number of lower LE included in it). Thus, for the above example of CG (see Figure 1, a) S = (4,2,0,0,0). The analysis of the vector S makes it possible to clearly distinguish local, independent LE, the value of S_i for which is zero, and integrated LE, which generalize, hierarchically include other LE (the S_i value for such LE is greater than zero). Thus, LE with $S_i = 0$ can be used according to the SCORM ideology as local independent learning objects - SCOs. They can be prepared independently of other learning facilities and placed together with the appropriate meta description in EER repositories for repeated reuse.

5) ***The degree of branching of the model of the content*** of the educational material. Let's denote this characteristic P and define it by the formula:

$P = E^T S = E^T (D_c - I)E.$ (6)

The P value characterizes the branching of the CG of the educational material. It is related to the number of LE and the number of levels of structuring by the following theorem.

Theorem 3. The degree of branching P of the content model of the educational material depends on the number of levels of structuring U and the number of LE n ($n \geq 1$, $n \neq 2$) and is associated with them by inequalities:

$n-1 \leq P \leq U(n-U);$ (7)

$n-1 \leq P \leq (n^2-1)/4$ *for odd* n = 1, 3, 5, 7, … ; (8)

$n-1 \leq P \leq (n^2-2)/4$ *for even* n = 4, 6, 8, … . (9)

Proof. The minimum level of branching at any $n \geq 3$ can be obtained if the number of structuring levels U=1 and all LE are directly related to the root. Then $P_{min} = n-1$, which is also true for n=1.

Analyzing the structuring schemes in Figure 3, you can get a general formula for determining the P value that is maximum possible for the given values of U and n: $P_{max}= U(n-U)$. Thus, inequality follows from the above (7). Further, substituting in the expression (7) inequality (5, 6), we get inequalities (8, 9), respectively.

6) ***Relative degree of branching*** of the model of the content of the educational material

$$\overline{P} = P / P_{\max} = P/(U(n-U)). \tag{10}$$

7) ***Average level of presentation of educational material***

$$\beta_{cp.} = \sum_{i=1}^{n} \beta_i / n. \tag{11}$$

8) ***Average level of assimilation of educational material***

$$\alpha_{cp.} = \sum_{i=1}^{n} \alpha_i / n. \tag{12}$$

9) ***Average level of awareness of educational material***

$$\gamma_{cp.} = \sum_{i=1}^{n} \gamma_i / n. \tag{13}$$

Averaged target indicators determined by formulas (11-13) allow you to compare various training materials with each other, predict the complexity of their presentation during development, the laboriousness of preparing exercises for training and control. The greater the value of these indicators, the higher the labor intensity. For example, if $1<\alpha_{cp.}<2$, then the exercises for training and control should include two blocks: the first at the level of acquaintance ($\alpha = 1$), the second at the level of knowledge reproduction ($\alpha = 2$).

For the above content model example (see Figure 1), integral characteristics: $n = 5$, $U = 2$, $\overline{U} = 1$, $S = (4,2,0,0,0)$, $P = 6$, $\overline{P} = 1$, $\beta_{cp.} = 3$, $\alpha_{cp.} = 1.6$, $\gamma_{cp.} = 2$.

Thus, using the integral characteristics of the content model, it is possible to analyze and compare various educational materials with each other, to assess the complexity of preparing EER already at the stage of their design.

5 Content model design automation

The algorithms discussed above make it possible to automate the process of preparing a content model [19]. The EER developer creates a set of LE in dialogue with the computer and establishes hierarchical relationships between them, filling in the values of the target indicators in the specification of the LE attributes. The computer program controls the structure of the CG, according to the rules of its construction, visualizes the CG, forms matrices of adjacency, reachability and distances, calculates the integral characteristics of the content model, forms the table of contents of the educational material for its export to the EER layout tool program (Figures 4, 5) [1].

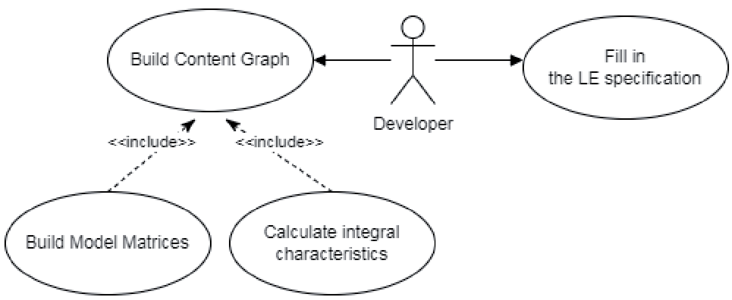


Figure 4 – Variant UML-diagram for using the computer program for the formation of the content model

[1] Here, when describing computer program scripts, unified modeling language (UML) diagrams are used *https://www.uml.org/*.

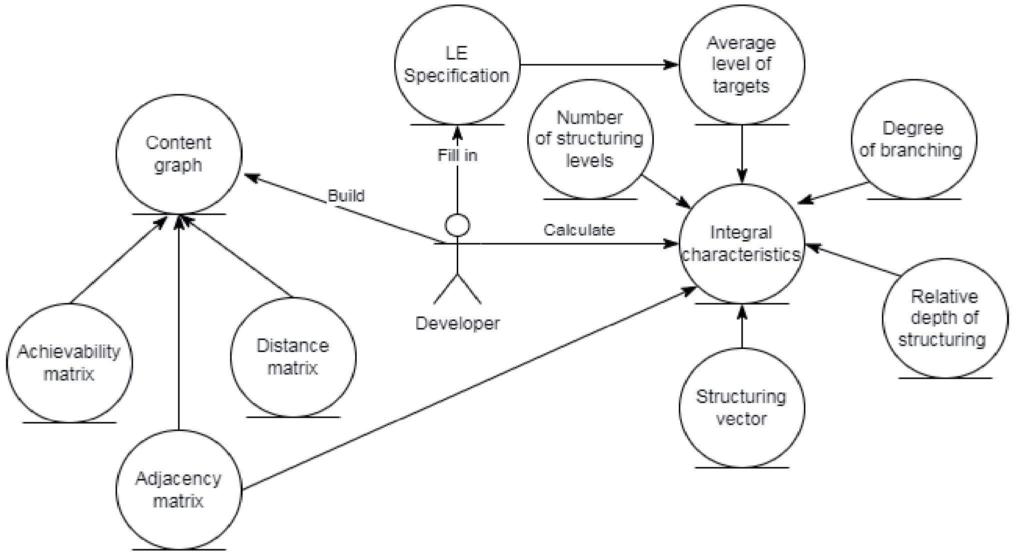


Figure 5 – UML interaction diagram between users and objects of the computer program for the formation of the content model

6 Example of structuring education material

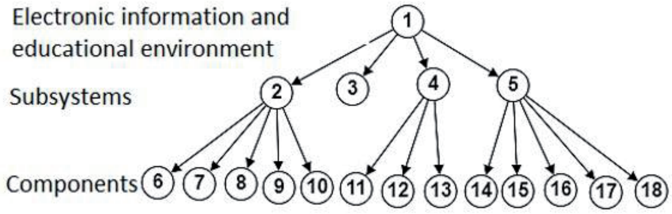
Consider the content model of one of the modules of our course for graduate students on methods and technologies of e-learning [20]. The topic of the module: "Electronic information and educational environment of an educational institution (EIEE EI)". The purpose of studying the module is to get acquainted with the typical functionality of EIEE EI. The education material of the module is based on the article [21] with some additions from other sources (Figure 6). The structure of the module is based on the presentation of EIEE EI as an organizational and technical system [21, p.147].

The content graph of the educational material has two levels of structuring: the first level is the subsystems of the EIEE EI, the second is the components of these subsystems (see Figure 6, a). Didactic attributes of LE are determined based on the contingent of students. These are graduate students who have experience with some components of EIEE EI, but do not have a complete system understanding of such systems.

For each LE, the didactic parameters are chosen to be the same (see Figure 6, b). The level of presentation of educational material is adopted by the analytical-synthetic $\beta = 2$ [22, p. 59] in accordance with its basic source [21]. The required level of assimilation is minimal – "Acquaintance" $\alpha = 1$ [22, p.60], taking into account the user nature of the potential interaction of students with the services of EIEE EI. But the level of awareness is maximum $\gamma = 3$, since students study the basic concepts of EIEE EI in this course, based on the experience of using the services of the system in different academic disciplines [22, p.62].

Integral characteristics of this content model: the number of LE $n = 18$, the number of levels of structuring of educational material $U = 2$, the maximum possible depth of structuring $Umax = 8$, the relative depth of structuring $\overline{U} = 0.25$, the structuring vector $S = (17,5,0,3,5,0,0,0,0,0,0,0,0,0,0,0,0,0)$, the degree of branching of the content model $P = 30$, the relative degree of branching $\overline{P} = 0.94$, the average level of didactic indicators $\beta_{cp.} = 2$, $\alpha_{cp.} = 1$, $\gamma_{cp.} = 3$.

Based on the requirements for the level of assimilation for each LE, the corresponding block of EER modulo, in addition to the information description, contains 3-5 exercises for comprehension and consolidation of the educational material. In total, about 65 such exercises of the first level of mastering the $\alpha = 1$ have been developed modulo, taking into account the level of presentation of the educational material $\beta = 2$ and the level of awareness $\gamma = 3$. The same set of test tasks is used to sample tests for the final control of knowledge by module.



a

No LE	Names of learning elements (LE)	α	β	γ
1	Electronic information and educational environment of an educational institution	1	2	3
2	Organizational subsystem	1	2	3
3	Marketing Subsystem	1	2	3
3	Subsystem of technical means	1	2	3
5	Subsystem of providing means	1	2	3
6	Students	1	2	3
7	Electronic Educational Resources Developers	1	2	3
8	Tutors	1	2	3
9	Managing personnel	1	2	3
10	Support staff	1	2	3
11	Equipment for students and staff	1	2	3
12	Telecommunication equipment	1	2	3
13	Distance Access Labs, VR, AR	1	2	3
14	Regulatory and legal support	1	2	3
15	Organizational support	1	2	3
16	Methodological support	1	2	3
17	Software	1	2	3
18	Bank of Electronic Educational Resources	1	2	3

b

Figure 6 – Content model of the Electronic information and educational environment of an educational institution topic: a – content graph; b – specification of learning elements attributes

7 Discussion of the results

Some elements of the above process of modeling the structure of EER were proposed by us earlier in [16, 23]. Models of this kind are useful for rational structuring of the content of the educational resource in the form of a set of hierarchically organized LEs. For many years, the authors have been using the concept and methods of building a content model when designing EER in various academic disciplines [22]. A number of colleagues in other educational institutions apply our developments in the design of their own EER [24].

The accumulated experience allows us to recommend starting to apply the proposed models with "manual" design using a pencil and paper. And only then proceed to automate this process. The use of a computer allows you to work with detailed content models consisting of several dozen LE, see the example in [22, p.75], which is practically unrealistic when preparing models manually.

The presentation of the structure of the electronic educational resource in the form of the content model considered in this article allows:

- to allocate the necessary material from the studied academic discipline, to divide it into separate educational elements, to present it in the form of a visual and observable scheme, to clearly define the didactic requirements for its presentation and study;
- to involve experts and customers of EER to discuss the completeness of the content and targets for its presentation and study already at the initial stage of EER design;

- to form a systematic (holistic) representation of the content of the EER, both among developers and users of EER (teachers and students);
- evaluate and compare various training materials in terms of volume, degree of structure, branching, give a forecast on the labor intensity, number and type of required exercises for training and control;
- develop EER in accordance with international SCORM specifications.

It is also important to emphasize that the process of building a content model allows even experienced teachers to take a fresh look at their educational material in terms of structure, form of presentation and requirements for its assimilation.

It is very useful in a guide to the study of any EER to give a model of content with structure and didactic requirements. This allows students to form a holistic visual representation of the structure of the educational material, motivate and orient them in terms of the thoroughness of its study.

Conclusion

The rules for constructing models of content of electronic educational content have been formulated. Models of this kind are useful for rational structuring of the content of the educational resource in the form of a set of hierarchically organized fragments of educational material. The mathematical properties of these models are discussed, their integral characteristics are introduced and strictly substantiated. The proposed approach to content modeling is well consistent with scorm's international e-learning specifications, complementing them with didactic targets, didactic design algorithms and analysis of educational materials. Algorithms for the formation and methods of representation of the content model allow to automate the process of its construction and didactic analysis in the form of a visual interactive dialogue of developers of electronic educational resources in instrumental author's environments.

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Received February 20, 2023. Revised March 1, 2023. Accepted March 3, 2023.

УДК 519.673 *Научная статья* DOI: 10.18287/2223-9537-2023-13-1-99-112

Проектирование онтологии содержания электронного учебного курса

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Аннотация

Моделирование знаний, тесно связанное с онтологиями, является важной семантической технологией и областью исследований. В статье рассматривается понятие модели содержания электронного учебного курса. В основу модели содержания положено структурирование содержание курса на отдельные фрагменты, называемые учебными элементами. Эти учебные элементы интегрируются в древовидный ориентированный граф. Модель содержания определена как совокупность такого графа и таблицы атрибутов учебных элементов с требованиями к дидактическим показателям их изучения. Формулируются правила построения моделей содержания электронного учебного курса. Обсуждаются математические свойства этих моделей и вводятся их интегральные характеристики. Предлагаемый подход к моделированию содержания хорошо согласуется с международными спецификациями электронного обучения *SCORM*, дополняет их целевыми показателями, алгоритмами дидактического проектирования и анализа учебных материалов. Алгоритмы формирования и способы представления модели содержания позволяют автоматизировать процесс её построения и дидактического анализа в форме визуального интерактивного диалога разработчиков электронных образовательных ресурсов в инструментальных авторских средах.

Ключевые слова: *электронное обучение, электронные образовательные ресурсы, структуризация учебного материала, модель содержания, древовидные ориентированные графы, SCORM.*

Цитирование: *Соловов А.В., Меньшикова А.А.* Проектирование онтологии содержания электронного учебного курса // Онтология проектирования. 2023. Т.13, №1(47). С.99-112. DOI:10.18287/2223-9537-2023-13-1-99-112.

Конфликт интересов: авторы заявляют об отсутствии конфликта интересов.

Рисунки

Рисунок 1– Пример модели содержания: а – граф содержания (ГС); б – спецификация атрибутов учебного элемента (УЭ); в – матрица смежности ГС; г – степени матрицы смежности ГС; д – матрица расстояний ГС; е – матрица достижимости ГС

Рисунок 2 – К свойству 1 графа содержания

Рисунок 3 – К теоремам 2 и 3

Рисунок 4 – *UML*-диаграмма вариантов использования компьютерной программы формирования модели содержания

Рисунок 5 – *UML*-диаграмма взаимодействия пользователей и объектов компьютерной программы формирования модели содержания

Рисунок 6 – Модель содержания темы «Электронная информационно-образовательная среда образовательного учреждения»: а – граф содержания; б – спецификация атрибутов учебных элементов

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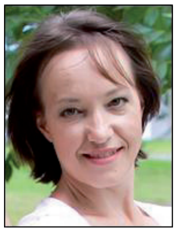

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Поступила в редакцию 20.02.2023, после рецензирования 1.03.2023. Принята к публикации 3.03.2023