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Оценка противоречивости логической структуры учебного плана

Цель исследования. *Основной целью создания учебного плана является упорядочение учебных дисциплин в соответствии с логикой процесса обучения, определенной взаимосвязями между основными понятиями дисциплин. Нарушение данной логики становится очевидным только непосредственно в ходе проведения учебных занятий.*

Большое разнообразие количественных методов используют показатели, которые не позволяют выявить структурные недоработки учебного плана. Это затрудняет процесс улучшения учебного плана.

Целью данной работы является продемонстрировать применение общего подхода к оценке структурной противоречивости систем применительно к оценке логической структуры учебного плана.

Материалы и методы. *В работе применен общий подход к оценке структурной целостности, разработанный на основе положений общей теории систем и теория графов. Подход предусматривает построение трех взаимосвязанных структурных моделей системы и определения с их помощью исходных данных для расчета показателя противоречивости структуры системы.*

Результаты. *Общий подход к оценке структурной целостности адаптирован для оценки логической структуры учебного плана. Разработаны три модели структуры учебного плана:*

– элементарная модель междисциплинарных связей;
– сетевая модель учебного плана;
– иерархическая модель учебного плана.

На основе параметров иерархической модели учебного плана с использованием трех адаптированных алгоритмов рассчитано значение показателя противоречивости структуры учебного плана по направлению подготовки Прикладная информатика.

Предложены рекомендации по изменению структуры исследуемого учебного плана для понижения степени его структурной противоречивости.

Заключение. *В результате проведенных исследований предложена методика, которая позволяет выявить возможные противоречия в структуре учебного плана и дать оценку его противоречивости.*

Как показали проведенные эксперименты, исследовать ручным способом учебные планы, количество дисциплин в которых превышает 50, крайне сложно. В связи с этим завершается разработка комплекса компьютерных программ, которые позволят автоматизировать оценку противоречивости больших учебных планов.

Ключевые слова: *интегрированные учебные программы, количественная оценка учебных планов, системный подход, теория графов, показатель противоречивости*

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Inconsistency evaluation of the curriculum logical structure

Purpose of the study. *The main purpose of creating a curriculum is to regulate academic disciplines in accordance with the logic of the learning process, defined by the relationship between the basic concepts of the disciplines. Violation of this logic becomes apparent only directly during the training sessions.*

A large variety of quantitative methods uses indicators that do not reveal structural deficiencies in the curriculum. This makes it difficult to improve the curriculum.

The purpose of this work is to demonstrate the application of a general approach to the assessment of the structural inconsistency of systems in relation to the evaluation of the logical structure of the curriculum.

Materials and methods. *The paper applies a general approach to the assessment of structural integrity, developed on the basis of the provisions of the general theory of systems and graph theory. The approach involves the construction of three interrelated structural models of the system and using them to determine the initial data for calculating the index of inconsistency of the system structure.*

Results. *The overall approach to the assessment of structural integrity is adapted to assess the logical structure of the curriculum.*

Three models of curriculum structure are developed:

Elementary model of interdisciplinary communication;
Curriculum network model;
Hierarchical curriculum model.

Based on the parameters of the hierarchical curriculum model, using three adapted algorithms, the value of the inconsistency index of the curriculum structure in the direction of preparation “Applied Informatics” is calculated.

Recommendations on changing the structure of the studied curriculum to reduce the degree of its structural inconsistency are proposed.

Conclusion. *As a result of the research, the methods were proposed that allow identifying possible contradictions in the structure of the curriculum and evaluating its inconsistency.*

As the experiments have shown, it is extremely difficult to study the curricula in a manual manner, the number of disciplines in which exceeds 50. In this regard, the development of a complex of computer programs that will automate the assessment of the inconsistency of large curricula is being completed.

Keywords: *integrated curricula, quantitative evaluation of curricula, system approach, graph theory, inconsistency indicator*

1. Introduction

One of the objectives of the Bologna Declaration [1] calls for the development of integrated training programs to ensure the mobility of curricula. Integrated training programs are built based on interchangeable blocks, allowing students to make their own choices. In other words, such programs give greater freedom of choice to students.

Interdisciplinary integration of the educational process is considered as the main mechanism for optimizing the structure of the knowledge model and the system of disciplines to form professional competencies both for each academic discipline separately and within the curriculum as a whole [2].

Many works have been devoted to solving problems of interdisciplinary integration (for example, [3-5]).

One of the main conditions for the implementation of interdisciplinary integration within the competence approach is the logical sequence of disciplines in the learning process, which is reflected in the curriculum. The main goal of creating a curriculum is to streamline the academic disciplines in accordance with the logic of the learning process, defined by the interrelationships between the basic concepts of disciplines. Violation of this logic becomes evident only directly during the conduct of training sessions.

The way out of this situation is to control the logic of the curriculum at the stage of its formation.

To assess the curricula, a sufficient number of quantitative and qualitative methods have been developed [6]. However, from the point of view of the problem of evaluating the logic of the curriculum, quantitative methods are preferable.

In this regard, there is a wide variety of quantitative approaches to the evaluation of curricula. Here are some of them:

- a Likert evaluation scale [6, 7];
- Curriculum mapping [6];
- a database-driven survey tool [6];
- Course progression maps [6];
- Anderson and Krathwhol's cognitive taxonomy [8];
- Porter's alignment index [8];
- a peer assessment [9];
- quantitative data in the form of standardized course evaluations [10];
- regression analysis method [11];
- a metacognitive approach [12].

These approaches mainly affect the functional aspect of curriculum evaluation. The indicators used are loosely related directly to the structure of the curriculum, with an assessment of the interrelationships of the disciplines. These approaches, first, have an illustrative character. They do not contain precise indications of structural flaws in the curriculum. This makes it difficult to improve the curriculum.

Thus, there is an actual problem of harmonizing disciplines in the curriculum in accordance with the logical sequence of their study in the educational process. There is a need to identify various inconsistencies in curriculum projects and develop recommendations for their elimination.

The purpose of this paper is to demonstrate the possibility of assessing the inconsistency of the logical structure of the curriculum by the example of professional disciplines.

2. Approach to evaluation the inconsistency of the curriculum

2.1. Contradictions in the structure of the system

Under the contradiction in the structure of the system, we understand the situation, which is characterized by the lack of ordering of the elements of the system. There are two kinds of similar contradictions: overt contradiction and covert contradiction.

An overt contradiction is manifested in the case when a pair of elements is in opposite relations (Fig. 1, a).

A covert contradiction arises in the case of "looping" of links, when, for example, one element is acting with respect to the second element, that in turn is acting with respect to the third element, and the third element is acting with respect to the first element. In other words, several elements are connected by a "chain" of unidirectional links (Fig. 1, b).

To identify contradictory links, the structure of the system should be presented in a hierarchical form. Then the contradictory links will be directed against the general orientation of the hierarchical structure.

Thus, to assess the degree of inconsistency of the system, it is necessary:

- To bring the structure of the system into a hierarchical form
- To identify possible contradictions in the links between the elements; to identify possible contradictions in the links between the elements
- To carry out calculations based on the quantitative char-

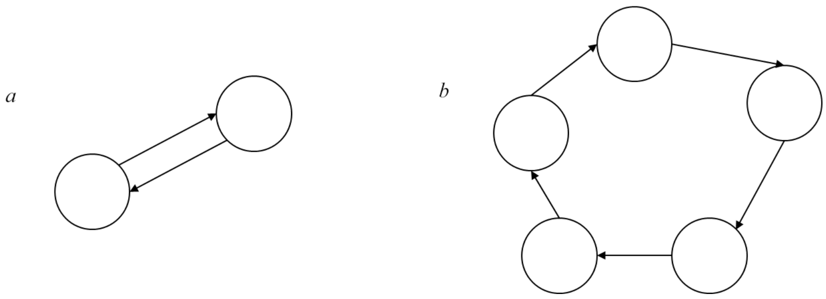

Fig. 1. Graph interpretation of: (a) overt contradiction; (b) covert contradiction

acteristics of the elements and the relationships between the elements, considering the revealed contradictions

For this purpose, an appropriate indicator, models and algorithms have been developed.

2.2. The measure of inconsistency

The indicator of inconsistency characterizes the presence of differently directed and (or) cyclic connections in the structure of the system (Fig. 1). The value of the indicator is in the interval [0, 1] and is calculated taking into account the ratio of the number of overt (N^o_R) and covert contradictory links (N^c_R) to the number of all connections (N_R) in the structure of the system [13].

The expression for calculating the indicator takes the form:

$$W = \frac{N_R^o + N_R^c}{N_R}, \quad (1)$$

N^o – number of overt contradictory relations;
N^c – number of covert contradictory relations;
N_R – total number of relations.

2.3. The Curriculum Structure Models

To construct the hierarchical structure of the curriculum, three models were developed [14]:

- The elementary model of interdisciplinary connections
- The network model of the curriculum
- The hierarchical model of the curriculum.

The elementary model of interdisciplinary connections (EMIC) reflects the use of educational material from other disciplines in the process of studying a separate discipline.

EMIC is a system of disciplines: one subsequent discipline and one or more previous disciplines:

$$d = \left\langle t^{sub}, \{t_j\} \mid t^{sub} \neq t_j \right\rangle, \quad (2)$$

t^{sub} – the subsequent discipline;
t_j – the previous discipline.

A directional connection between each previous discipline and the subsequent discipline (t^{sub}, t_j) is interpreted as an “application”.

Then for the k-th EMIC, a set of relations are formed:

$$r_{d_k} = \{(t_k^{sub}, t_j\}, \quad (3)$$

r_{dk} – the set of relations between the subsequent and previous disciplines in EMIC d_k.

The network model is the result of the integration of all EMIC. It is the set of the disciplines of the curriculum and the set of connections between disciplines.

The meaning of EMIC integration is reduced to combining the disciplines from each EMIC d_k into one set of disciplines T of the curriculum:

$$\bigcup_{k=1}^{l} t^{d_k} \rightarrow T = \{t_j\}, i = \overline{1,n}, \quad (4)$$

n – the total number of disciplines.

An adjacency matrix R is obtained in the process of combining the r^{dk} connections from the EMIC:

$$\bigcup_{k=1}^{l} r^{d_k} \rightarrow R = \|r_{ij}\|, i, j = \overline{1,n}, \quad (5)$$

r_{ij} – connection between i-th and j-th disciplines.

As a result, the network model S of the curriculum is constructed:

$$S = \langle T, R \rangle. \quad (6)$$

Thus, the integration of EMIC models is the joint implementation of two processes:

- Associating of disciplines
- Associating of connections between disciplines

The hierarchical model of the curriculum is obtained as a result of the transformation of the network model:

$$S = \langle T, R, U \rangle. \quad (7)$$

For this purpose, the levels of distribution of disciplines are determined: $U = \{u_i\}$, $i = 1, n$. The value of the element u_i corresponds to the level number in the hierarchy that occupies the i-th discipline. The numbering starts at the top level. In the hierarchical model, the disciplines are ordered according to the levels of the hierarchy in accordance with the directed links between them: at the upper level are placed disciplines that do not have the previous disciplines; at the lower level - disciplines that do not have subsequent disciplines. Levels of the hierarchy reflect the temporal sequence of the study of disciplines of the curriculum. Disciplines placed on the same level of learning u_i are studied at the same time interval of training.

2.4. The Algorithms for constructing curriculum models

The hierarchical model of the curriculum is the basis for preparing the initial data for calculating the measure of inconsistency. For this purpose, three algorithms have been developed:

- Revealing overt contradictions
- Calculating of paths
- Revealing covert contradictions

The content of the algorithm for revealing overt contradictions lies in the search for all bidirectional connections between the disciplines. The initial data for revealing overt contradictions is the adjacency matrix of the disciplines $R = \|r_{ij}\|$, the result is the set of pairs of disciplines $W^o = \{(t_i, t_j)\}$; each pair corresponds to one overt contradiction.

For this purpose, a pairwise comparison of the values of two elements r_{ij} and r_{ji}, which have opposite (backward) indices, is performed successively. In the case of equality of these elements 1, the corresponding pair of disciplines (t_i, t_j) is included as an element in the set W^o:

$$(t_i, t_j) \rightarrow W^o, \text{ if } r_{ij} = r_{ji} = 1. \quad (8)$$

The content of the algorithm for calculating paths consists in the search for sequences (chains) of disciplines. Each such chain is built because of a step-by-step transition from discipline without

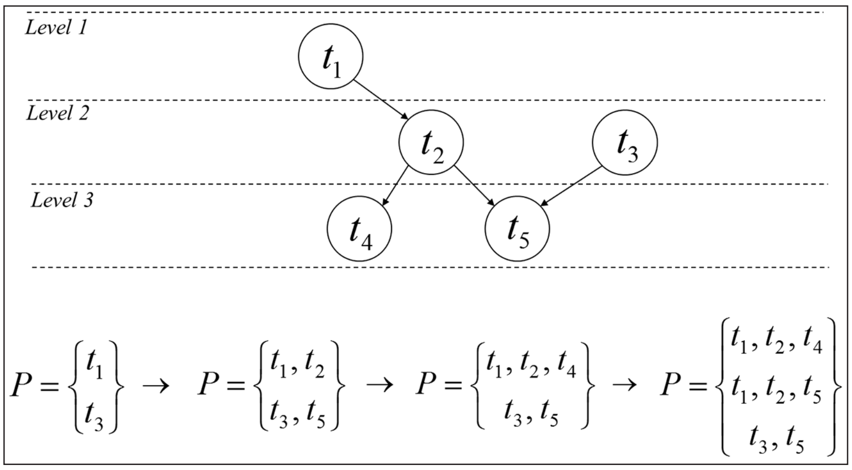

Fig. 2. An example of execution of the algorithm for calculating paths

previous disciplines to discipline without subsequent disciplines. This transition is carried out from one discipline to another by unidirectional connections. These sequences (chains) of disciplines are called paths.

The adjacency matrix of the disciplines $R = \|r_{ij}\|$ is the initial data for the algorithm. As a result of the algorithm, a set of discipline pathways $P = \{p_k\}$are obtained. Each element p_k (kth path) is a set of ordered disciplines $p_k = \{t_i, ..., t_j\}$:

$$p_k \rightarrow P, if \sum_{j=1}^{n} r_{ij} = 0. \qquad (9)$$

To prevent “loops” during the calculation of paths $p_k = \{t_i, ..., t_j\}$, a return to the higher level of the hierarchy is restriction to sequentially viewed links.

The algorithm is implemented in several stages, which are performed for each path.

The sequence of the above steps of the algorithm is shown in Fig. 2.

The content of the algorithm for revealing covert contradictions lies in the search for such links between two disciplines t_i and t_j that meet the following conditions:

- The discipline t_i is related to the discipline t_j by the “parent-child” relationship
- The discipline t_i occupies a level whose number does not exceed the number of the level occupied by the discipline t_j
- The connection between the disciplines t_i and t_j does not express an overt contradiction in the hierarchy

Thus, each such pair (t_i, t_j) points to one or more loops of disciplines that contain covert contradictions.

The initial data for revealing the covert contradictions are:

- The set of paths $P = \{p_k\}$
- The set of overt contradictions $W^o = \{(t_i, t_j)\}$

The main stages of the algorithm are:

- Sequential analysis of each path p_k to identify duplication of disciplines
- Identification of loops
- Formation of the set of pairs of related disciplines from loops
- Exception from this set of overt contradictions

As a result, set $W^c = \{(t_i,t_j)\}$ are obtained. Each pair (t_i, t_j) is a covert contradiction.

After the application of the algorithms, the initial data are obtained for calculating the inconsistency index:

- The number of overt contradictions (N^o)
- The number of covert contradictions (N^c)

The value of the inconsistency indicator B is obtained by substituting these data into the formula (1).

3. An example of evaluation of the inconsistency of a curriculum

To illustrate, let us consider the assessment of the inconsistency of the curriculum “Applied Informatics”.

For the formation of EMIC, a survey card of experts is used (Table 1). The first two columns in the card are allotted to indicate the number and name of the discipline, which are called “subsequent discipline” in EMIC. The third column contains expert opinions on the disciplines that are used to study the disciplines listed in the second column. In other words, the second column is “previous disciplines”.

Thus, each line of the expert survey card is one EMIC.

Because of the integration of EMIC into the network model, 26 disciplines and 114 links between disciplines were obtained.

The hierarchical model of the curriculum includes 13 levels (Fig. 3).

In the hierarchical model, there are 5 contradictory pairs that contain 10 overt contradic-

Table 1

A fragment of the expert survey card

Discipline code	Discipline name	Codes of previous disciplines
1	Computing systems, networks and telecommunications	4, 13, 22, 24, 25, 26
2	Operating Systems	4, 19, 22, 24, 25
3	Software Engineering	7, 19, 25
4	Information systems and technologies	5, 11, 20
...	...	...
26	Physics	

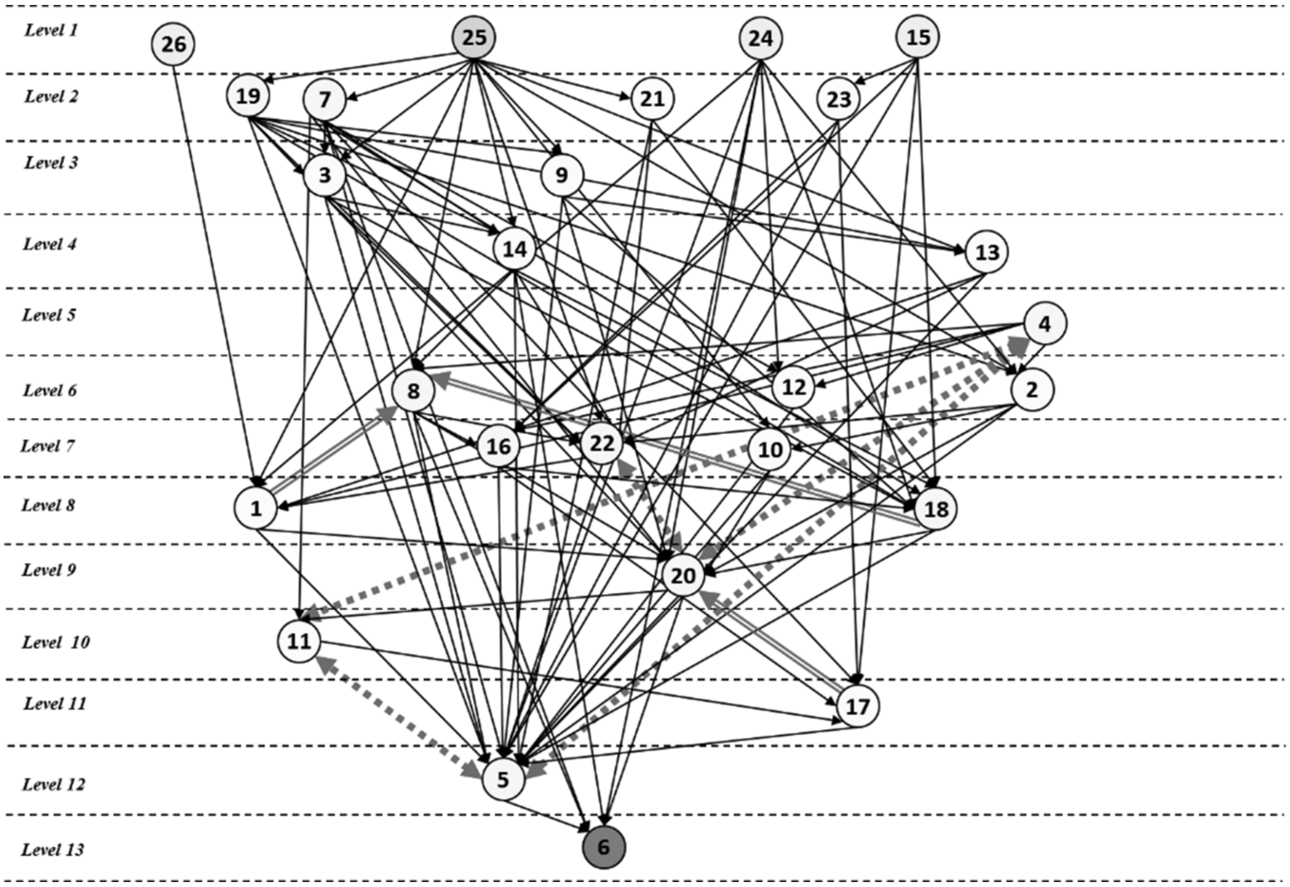

Fig. 3 A example of a hierarchical structure of the curriculum

tory links (Table 2), and 3 cycles that contain 9 covert contradictory links (Table 3).

As a result, the calculation of the inconsistency indicator of the curriculum "Applied Informatics" was carried out:

$$W = \frac{N_R^o + N_R^c}{N_R} = \frac{10+9}{114} = 0{,}17. \quad (10)$$

Table 2

Overt contradictions between disciplines

Discipline codes	Discipline names
4↔11	Information systems and technologies ↔ Information Management
4↔20	Information systems and technologies ↔ Corporate Information Systems
4↔5	Information systems and technologies ↔ Designing of information systems
11↔5	Information Management ↔ Designing of information systems
2↔22	Operating Systems ↔ Development of network software

Table 3

Covert contradictions in the chains of disciplines

Discipline codes	Discipline names
8→22→1→8	Information Security → Development of network software → Computing systems, networks and telecommunications → Information Security
8→16→18→8	Information Security → Multimedia Technologies → Computer analysis → Information Security
20→11→17→20	Corporate Information Systems → Information Management → Electronic business → Corporate Information Systems

The obtained value of the inconsistency indicator allows us to conclude that the estimated curriculum does not correspond to the maximum possible systemic representation. To increase this indicator, we can suggest some recommendations.

For overt contradictions, pairs of conflicting disciplines are considered by experts who have formed elementary models for each of these disciplines. They coordinate their opinions based on a detailed analysis of the subjects of each discipline and develop a justified common opinion about the disruption of one of the contradictory links. This is equivalent to removing one of the discipline from the corresponding EMIC model.

For covert contradictions, the most frequent pairs of disciplines are identified, and the same operations are carried out with these pairs as for overt contradictions. The only difference is the result of agreeing the opinions of experts. Here, in addition to breaking the connection between a pair of disciplines, there may be a variation in the direction of this connection.

Conclusion

As a result of the studies, a method is proposed that allows to identify possible contradictions in the structure of the curriculum. In the presence of contradictory links, it is preferable to exclude those that are directed against the general orientation of the links in the hierarchical model of the curriculum. During practical application of the method, many procedures associated with the implementation of manual operations it was revealed. As experiments have shown, to study manually the curriculum, the number of disciplines in which more than 50 is extremely difficult. In this regard, programs are being developed that will automate the evaluation of the inconsistency of large curricula.

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