DATALOGIC RELATION MODEL FOR AUTOMATED EVALUATING THE SEMANTIC INTEGRITY OF TEST TASKS SETS BY MACHINE LEARNING MEANS

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Testing is the process of testing a person's knowledge, skills, and competencies using a system of questions and tasks. It can be used for various purposes. Testing helps determine how well students have understood and remembered the material they have learned [1]. In professional activities, testing is used to determine the level of competencies of employees, their ability to perform certain tasks, and meet the standards of the profession. Testing is an effective tool for selecting the most suitable candidates for certain positions by assessing their professional knowledge, skills, and compliance with the employer's requirements. To confirm the qualifications of specialists in various fields, testing is used as part of certification programs, which allows you to establish the specialist's compliance with established standards [2]. Testing can also be a self-assessment tool, helping people determine their own level of knowledge and skills, identify strengths and weaknesses, and plan further training or development. Thus, testing plays an important role in many areas of life, providing a systematic and objective assessment of knowledge, skills, and competencies [3].

With the development of technology, online testing has emerged, which significantly expands the capabilities of traditional testing. Online tests can be taken at any time and in any place where there is Internet access. Online testing platforms offer a wide range of settings, which allows you to adapt tests to the needs of a specific audience. The results of online tests are available immediately after their completion, which allows you to quickly assess the level of knowledge and skills of participants. The automated assessment system in online tests minimizes the risk of subjective assessment by teachers [4].

Today, online testing is very popular in the IT field. Since digital technologies penetrate all areas of life, which leads to a rapid increase in demand for qualified IT specialists. This demand is felt not only by technology companies, but also by banks, retail, medical institutions, government agencies, etc. Therefore, IT testing is becoming increasingly popular [5].

Thanks to online testing platforms, you can easily organize a mass selection of candidates, assessing their knowledge and skills in the IT field. Tests allow you to determine which skills need improvement, which makes it possible to plan your

training and self-development. There are IT tests on different topics and levels of difficulty, which allows you to choose a test that meets the needs of a particular candidate or specialist [6]. There are also online IT testing platforms that offer tests that match the format and complexity of real professional exams for a master's degree. By taking mock tests, students get used to the exam format, which reduces their anxiety and fear during the real exam, and helps students learn how to properly allocate time for tasks. Thanks to mock tests, students can develop their own strategies for overcoming difficult tasks that may occur on the exam [7].

In contemporary education, significant emphasis is placed on enhancing the quality and effectiveness of educational resources, particularly test tasks, which serve as a crucial means for evaluating students' knowledge and comprehension. Nonetheless, traditional assessment methods often focus solely on verifying the accuracy of answers, disregarding their semantic coherence and contextual relevance [8]. This limitation may result in less objective evaluations and suboptimal utilization of educational materials.

Within the subject area of information technology, the task of creating effective tools for testing knowledge and skills is becoming relevant. Traditional assessment methods, such as written exams or oral interviews, may not be effective enough due to their limited flexibility, subjectivity of assessment and significant time consumption. In this context, web-based platforms for testing knowledge and skills offer a modern solution that provides automation of the testing process, user-friendliness and objectivity of assessment. Such platforms can significantly improve the process of learning and advanced training, as well as contribute to a more accurate and fair assessment of professional competencies.

The process of learning with a teacher usually occurs when the teacher explains in detail to the students the complex aspects of the educational material, demonstrates various practical exercises, and the students also have the opportunity to ask questions if they have difficulties understanding the presented material. A learning situation occurs when people find themselves in a situation that is not yet familiar to them and acquire certain knowledge and skills there. It sets a task for a person and requires active participation from him. Learning situations are a good source of new opportunities and development. The third component of the learning process is educational materials. This stage of learning occurs through a systematic process. That is, a person first reads some information, analyzes it, and then tries to understand and remember it. After that, person can already apply this information [2].

Educational materials can be presented in various components. Most often, this is done using text. It contains many theories, facts, rules, examples for learning information. Information can also be presented using formulas or tables, which usually have a more organized way of displaying information. Diagrams and graphs are often used to visually display relationships between different elements. And illustrations are often used to show specific objects, processes, or even for interest.

Today, testing has reached a new level of popularity, due to its speed and ease of creation and implementation. Online testing provides an opportunity to quickly and

effortlessly test everyone's knowledge [9]. There are five most popular types of test questions:

1. With one correct answer, a question format where the user needs to choose only one answer option from all available ones. This type is the most common among tests and is used to determine the main advantages among a set of options.

2. Multiple choice, this type of question is one of the most popular, its content is to choose, on average, from 2 to 5 correct answers. It allows you to determine how much the test taker can analyze and synthesize the information provided.

3. Short answer question, as a rule, this question format requires a concise, concise and clear answer, which can be factual, explanatory or combines two, and consists of one or two words.

4. Matching, consists of instructions, columns of statements and columns of answers. It is also a variety of the multiple choice format.

5. True or false, this question consists only of a statement, and allows you to choose the correct answer with a probability of 50%.

However, it is worth understanding the fact that testing does not always fully cover all the key terms in the required material. To avoid this problem, it is worth using semantic analysis of the text. The main goal of semantic analysis is to comprehend the content of the text and understand the meaning of words. Thanks to semantic analysis, a brief summary of the text, its essence and idea are determined. This analysis allows you to identify key terms and phrases that most affect the content of the text and express its central themes [10]. Thanks to semantic analysis, it becomes much easier to understand the key concepts and ideas that are most important to the author. That is, this analysis is usually used to process a large amount of data in order to quickly identify key concepts and the main idea of the text. The approach for automated evaluation of test tasks in relation to the semantic aspects of educational materials is grounded in the intelligent analysis of textual content. By leveraging computational algorithms and natural language processing techniques, this method assesses the semantic alignment between test questions and the instructional content. It enables automated determination of how well test answers align with the underlying content and meaning of the educational materials.

An intelligent system designed for the automated assessment of test task conformity to the semantic structure has been developed based on this method. The framework (Figure 1) provides a clearer understanding of the system's operation, presenting the optimal sequence of steps for effective task execution in a structured manner.

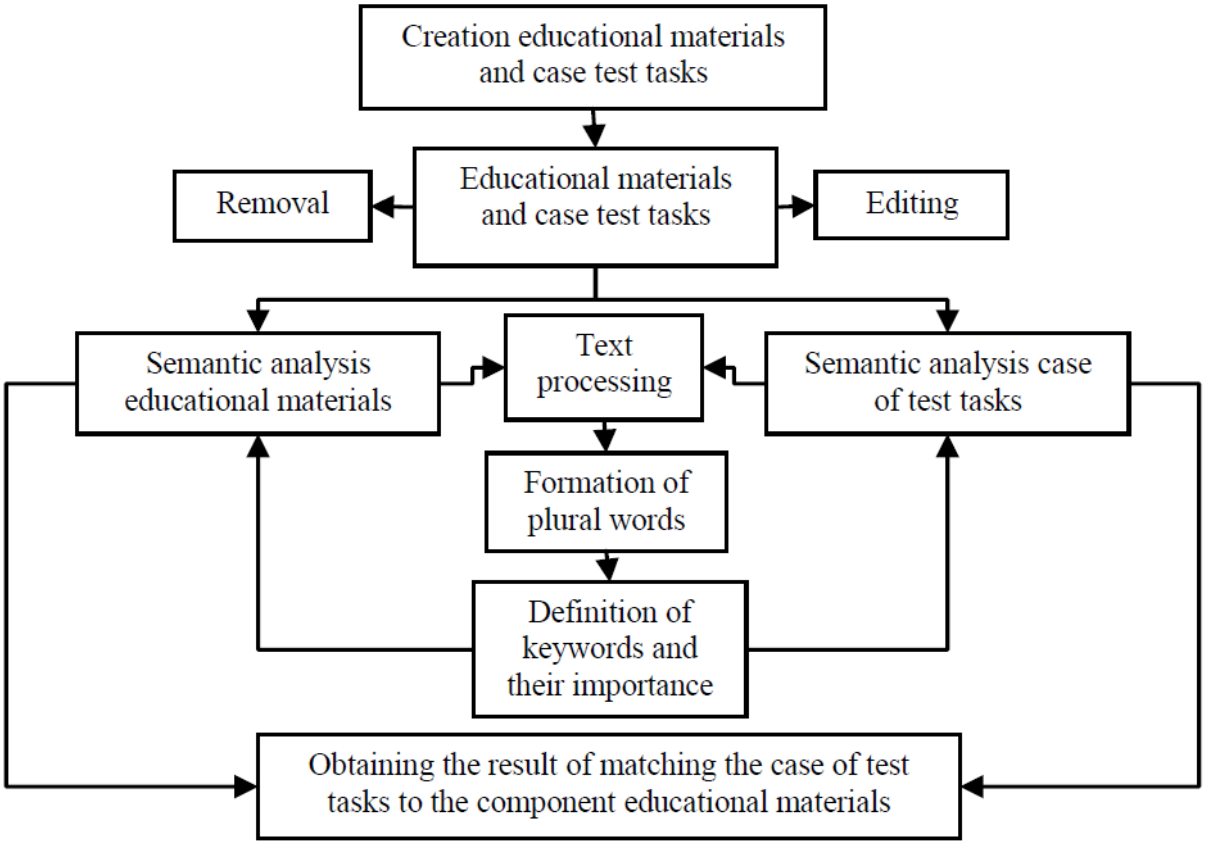

Figure 1. Generalized scheme of functionality of intelligent system for automated evaluating the semantic integrity of test tasks sets by machine learning means

The proposed scheme illustrates that the initial stage in utilizing the application involves the user inputting data, specifically creating educational materials and corresponding test tasks. Once these are created, users gain access to various functions such as deleting or editing the materials and performing semantic analysis. The "semantic analysis" feature encompasses several steps: text lemmatization (removing punctuation, converting text to lowercase, and eliminating stop words), word set formation (breaking text into individual words), and identifying key terms along with their significance. The final functionality available to users is obtaining results, specifically an evaluation of how well the test tasks align with the semantic components of the educational materials.

To represent the structure of the software application visually, a schematic of the intelligent system for automated assessment of test tasks conformity to the semantic structure of educational materials has been developed (Figure 2). The scheme indicates that the user interaction subsystem allows for adding, editing, and deleting educational materials and associated test tasks, with all modifications being stored in corresponding files. The data preprocessing subsystem prepares the data stored in the database [11, 12] for further semantic analysis [13, 14]. Subsequently, the semantic analysis subsystem processes the preprocessed data to automatically generate keywords, determine their relevance, evaluate the alignment of test tasks with the semantic elements of educational materials, and display the final result.

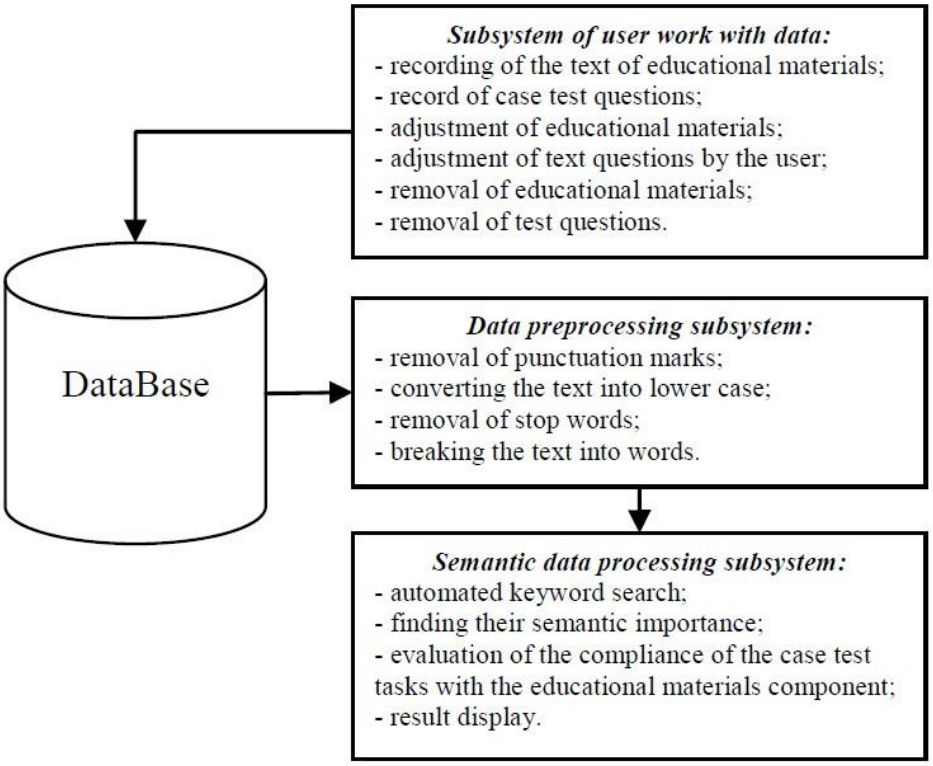

Figure 2. Scheme of intelligent system for automated evaluating the semantic integrity of test tasks sets by machine learning means

Figure 3 shows a datalogical model of a database for testing information technology knowledge and skills, demonstrating the database structure, its tables, and the relationships between them. The database contains the following tables: «users», «type_users», «courses», «testing_in_cours», «results», «passed_tests», «testing», «answers_to_questions», «answer», «type_answer», «question», «question_test».

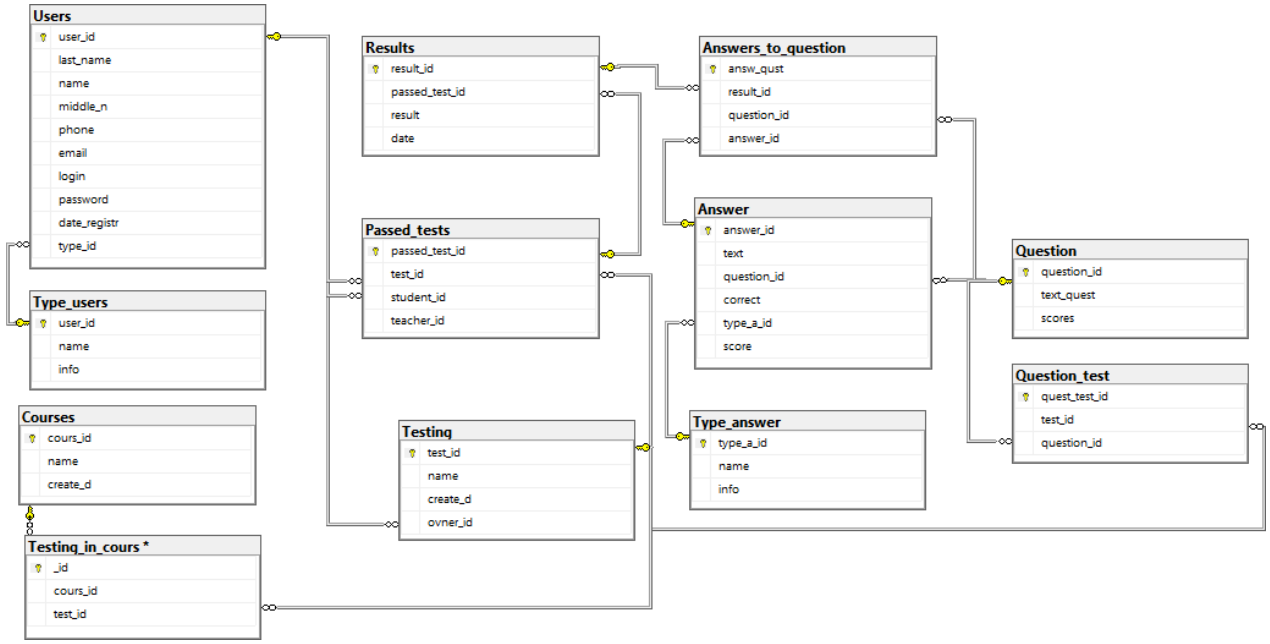

Figure 3. Datalogic relation model for automated evaluating the semantic integrity of test tasks sets

The table "type_users" describes the types of users stored in the database and contains the user role name and the user function group. The table attributes are: a unique table record identifier "id" (INT), the user role name "name" (VARCHAR), and the user function group name "info" (VARCHAR).

The table "users" contains information about users, including their personal and contact details, registration details, and the assigned role. Table attributes: unique table record identifier "id" (INT), user last name "last_name" (VARCHAR), user first name, "name" (VARCHAR), user middle name "middle_n" (VARCHAR), mobile phone number "phone" (VARCHAR), user email address "email" (VARCHAR), user login "login" (VARCHAR), user password "password" (VARCHAR), system registration date "date_register" (DATE) and user role "type_id" (INT)/

The "Courses" table contains information about courses, including their unique identifiers, names and creation dates. Table attributes: unique table record identifier "id" (INT), category name for which testing is performed "name" (VARCHAR), category creation date "create_d" (DATE).

The "Testing" table contains information about tests, including their unique identifiers, names, creation dates and authors. Table attributes: unique table record identifier "id" (INT), test subject "name" (VARCHAR), test owner "owner_id" (INT). The "Testing_in_cours" table is designed to store data about testing conducted within courses. It includes information necessary to link tests to their respective courses and test types, and also provides a unique identifier for each test task. Table attributes: unique table record identifier "id" (INT), link to the corresponding course record "cours_id" (INT), link to corresponding test record "test_id type_t_id" (INT).

The "type_answer" table is designed to store data about the different types of answers used in tests. It contains information necessary to identify each type of answer and describe its main characteristics. Table attributes: unique table record identifier "id" (INT), answer category name "name" (VARCHAR), information about the format of the answer type "info" (VARCHAR).

The "question" table is designed to store data about questions used in tests. It contains information necessary to identify each question, its text description and the number of points that can be obtained for it. Table attributes: unique table record identifier "id" (INT), text content of the question "text_quest" (VARCHAR), weight of the question in points "scores" (NVARCHAR).

The "answer" table contains data on the answers provided by users to questions in tests. It includes information necessary to identify each answer, describe its text, link to the corresponding question and answer type, as well as information about correctness and evaluation. Table attributes: unique table record identifier "id" (INT), test content of the answer "test" (VARCHAR), link to the corresponding test question "question_id" (INT), correctness value of the answer "correct" (BIT), link to the corresponding answer type "type_a_id" (INT), weight of the answer in points "score" (NVARCHAR).

The "Question_test" table is designed to store relationships between questions and the tests to which they belong. It contains information that allows you to determine which questions are included in each test. Table attributes: unique table

record identifier "id" (INT), link to the corresponding test record "quest_test_id" (INT), link to the corresponding question "question" (INT).

The “Passed_tests” table is designed to store information about the tests that students have taken and the grades they have received. It contains data necessary for tracking test results and analyzing student performance. Table attributes: unique table record identifier “id” (INT), test that was passed “test_id” (INT), link to the corresponding test participant record “student_id” (INT), link to the corresponding test author record “teacher_id” (INT).

The “Results” table is designed to store detailed information about the test results passed by participants. It includes data necessary for tracking and analyzing each test, including grades, completion time, and other key indicators. Table attributes: unique table record identifier “id” (INT), link to the corresponding test record “passed_test_id” (INT), scores received “result” (NVARCHAR), test completion time “date” (DATETIME).

The table "Answers_to_question" stores the relationships between students' answers to test questions and the test results themselves. It contains data that allows you to track which answers each student gave to each question. Table attributes: unique table record identifier "id" (INT), link to the corresponding result record "result_id" (INT), link to the corresponding question record "question_id" (INT), link to the corresponding answer record "answer_id" (INT).

The intelligent system accepts selected educational materials and a corresponding set of test tasks related to a specific topic as input. For this purpose, a dedicated editor for educational materials is integrated into the application (Figure 4). After the initial content is loaded, users can edit and save modifications to the educational materials and test questions.

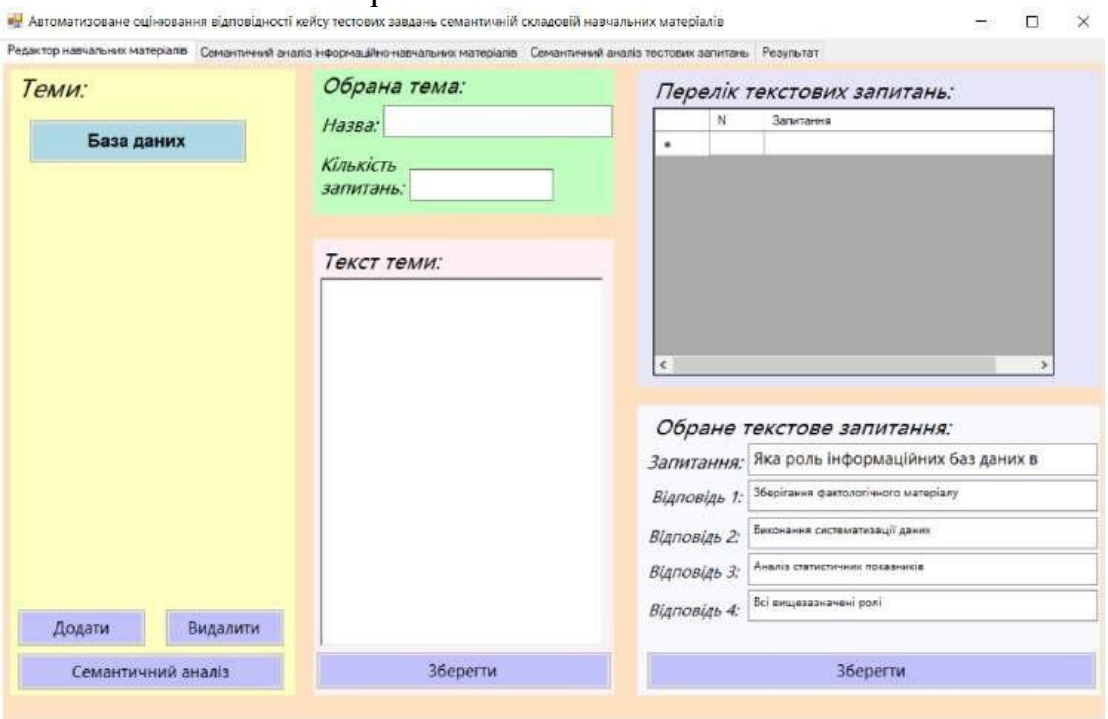

Figure 4. Screenshot of the first tab of the intelligent system for automated evaluating the semantic integrity of test tasks sets by machine learning means

Upon receiving the input data, the system initiates processing by filtering the educational materials. This step includes removing punctuation, numbers, and converting text to lowercase. Subsequently, vectorization is applied, transforming the content into an array of words. The same preprocessing steps are carried out for the test questions.

With the lists of words generated, the system proceeds to semantic analysis. Using the DE method, a set of keywords is extracted from the educational materials. This process includes forming an initial word set, removing stop words (such as prepositions, pronouns, conjunctions, and numerals), calculating distances between words, and determining their significance (Figure 5). Similarly, the test task keywords are analyzed and quantified (Figure 6).

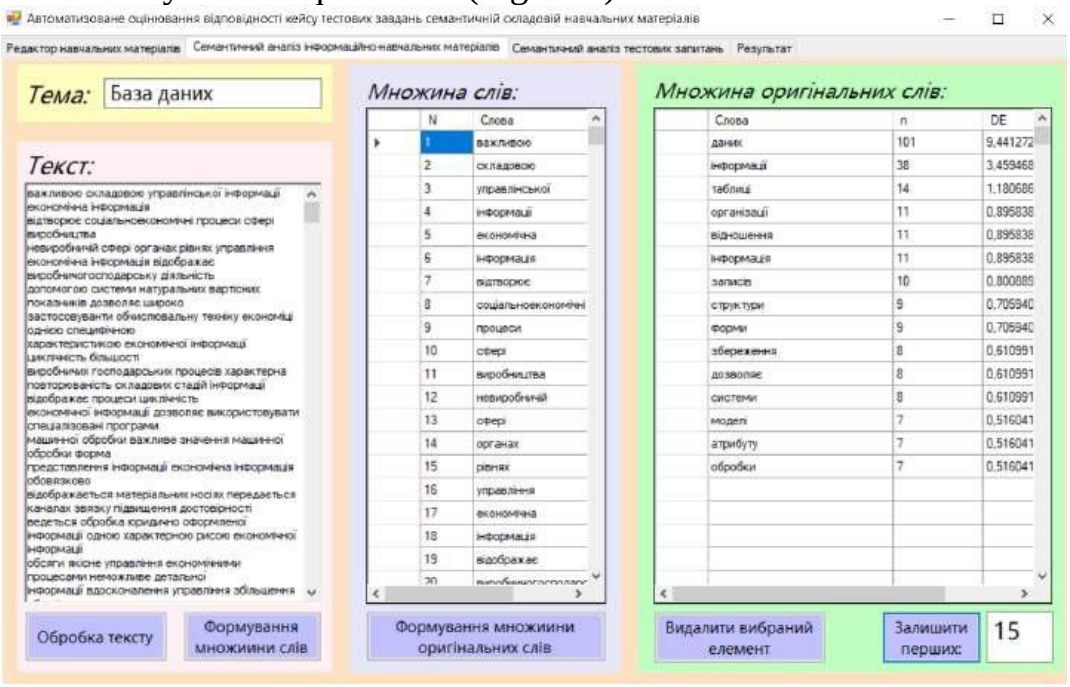

Figure 5. The result of semantic analysis of educational materials in the intelligent system for automated evaluating the semantic integrity of test tasks sets

Finally, the system compares the key terms from the educational materials with those from the test tasks, evaluating the semantic alignment. The intelligent system verifies whether all significant terms in the educational materials are adequately represented in the test questions, thereby ensuring the semantic coherence of the test tasks with the educational content.

The output of the intelligent system for automated evaluation of the alignment between test tasks and the semantic structure of educational materials is a numerical score indicating the degree of conformity. This assessment is based on an in-depth analysis of the textual content of both the educational materials and the test tasks. Additionally, the system provides users with an expert recommendation regarding which key terms from the educational materials should be incorporated into the test questions. By clicking the "Generate Conclusion" button (Figure 7), the user can access this functionality, resulting in a comprehensive report generated by the system.

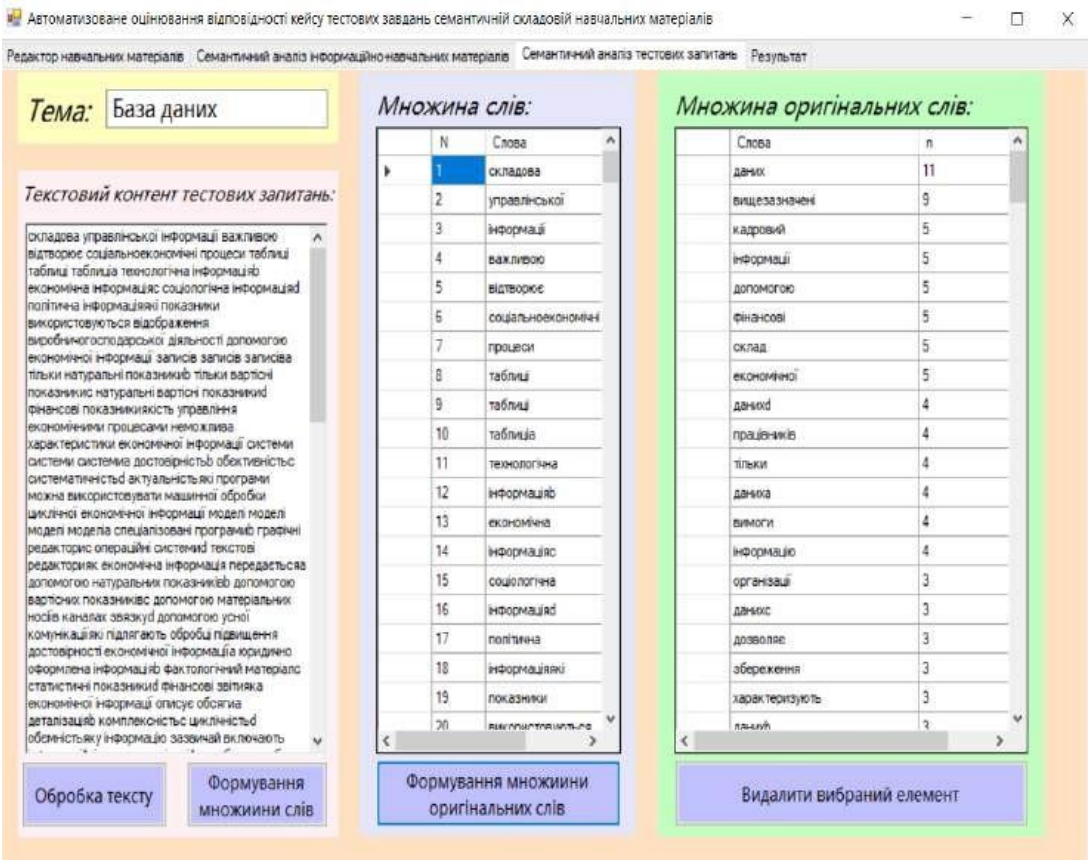

Figure 6. Result of semantic analysis of test tasks set in the intelligent system for automated evaluating the semantic integrity of test tasks sets

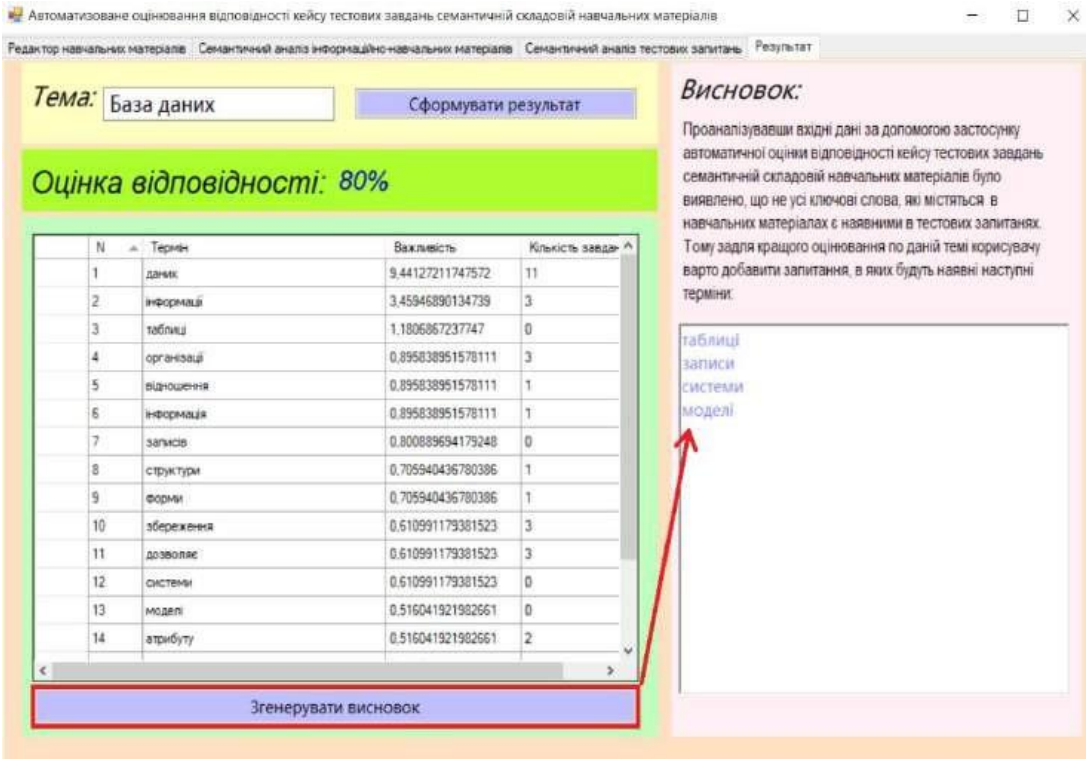

Figure 7. The result of the analysis of the semantic integrity of test tasks sets by machine learning means

During the development of the intelligent system, a class diagram was created to illustrate its structure (Figure 8). The diagram identifies the main classes, which include "Form1," "Text Processor," "Read Text," and "Semantic" [15].

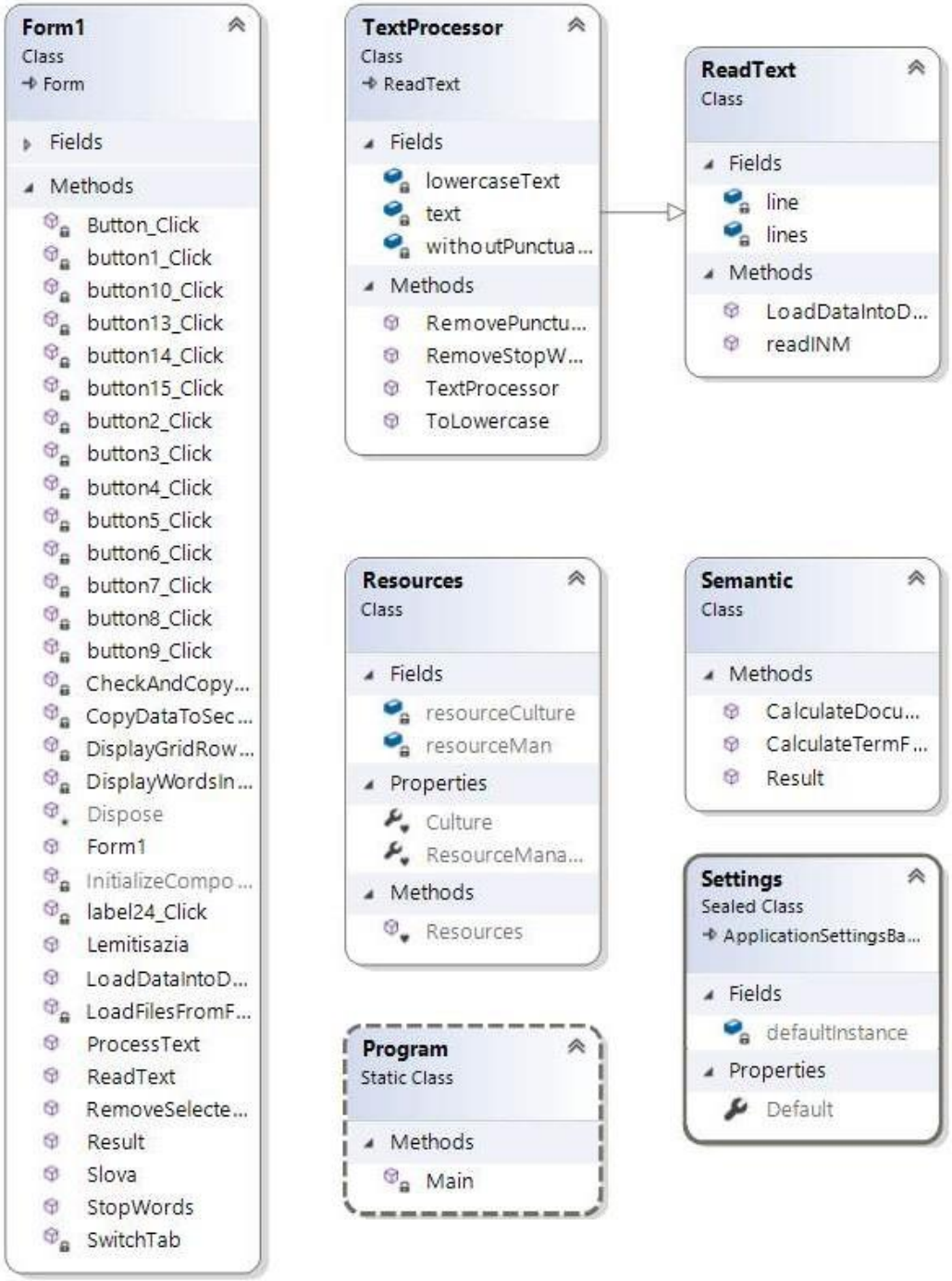

Figure 8. Class diagram of intelligent system for automated evaluating the semantic integrity of test tasks sets by machine learning means

The "Form1" class serves as the core of the application, managing interactions with various form components. It contains a private field, folderPath, which stores the path to the folder containing files. The class implements methods such as ReadText() and LoadDataIntoDataGridView() to handle data output to relevant DataGridView components. It also includes methods that are triggered by button presses, each executing the specific functionality assigned to the respective button.

The "ReadText" class manages the reading of data from text files. The readINM() method handles the retrieval of text from educational materials, constructing the file path and returning its content as a string. Similarly, the LoadDataIntoDataGridView() method processes the text from test task cases, reading the file line by line and returning an array of lines.

The "TextProcessor" class is dedicated to processing input text. Its methods include RemovePunctuation(), which eliminates punctuation marks; ToLowercase(), which converts text to lowercase; and RemoveStopWords(), which filters out stop words from the text.

The "Semantic" class focuses on semantic analysis, containing two methods: CalculateTermFrequency and CalculateDocumentImportance. The former calculates the frequency of each term in the text, while the latter determines the importance of words based on variance scores.

Therefore, the datalogic relation model for automated evaluating the semantic integrity of test tasks sets was designed. The developed intelligent system has significant potential for use in educational institutions and organizations where assessing the alignment of test tasks with educational materials is critical. By automating this evaluation process, the system ensures objectivity and reliability in the results.

To enhance the system further, several areas for improvement can be explored. These include refining semantic analysis algorithms through the integration of more specialized techniques, developing a more precise algorithm for comparing texts with test questions, and expanding the system's functionality to cater to a broader range of educational contexts.

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