{
⇐ *subdividing*:*
{ • *judgment question of choosing true*
• *judgment questions of choosing false*
}

V. PROBLEM SOLVER

One of the most important components of every intelligent system is the problem solver, which provides the ability to solve a variety of problems. The problem solver of any ostis-system (more precisely, the sc-model of the ostis-system problem solver) is a hierarchical system of knowledge processing agents in semantic memory (scagents) that interact only by specifying the actions they perform in the specified memory [1], [4].

Therefore, a problem solver for automatic generation of test questions and automatic verification of user answers has been developed based on the proposed approach, and its hierarchy is shown below in SCn-code:

Problem solver for the automatic generation of testquestions and automatic verification of user answers

⇐ *decomposition of an abstract sc-agent*:*

{ • *Sc-agent for automatic generation of test question*

⇐ textitdecomposition of an abstract sc-agent*:

{ • *Sc-agent for quick generation of test questions and test papers*

• *Sc-agent for generating single type of test questions*

• *Sc-agent for generating a single test paper*

}

• *Sc-agent for automatic verification of user answers*

⇐ *decomposition of an abstract sc-agent*:*

{ • *Sc-agent for automatic scoring of test papers*

• *Sc-agent for calculating similarity between answers to objective questions*

• *Sc-agent for calculating the similarity between answers to definition explanation questions*

• *Sc-agent for converting a logical formula into PNF*

• *Sc-agent for calculating the similarity between the answers to proof questions and problem-solving task*

}

}

The function of the sc-agent for quick generation of test questions and test papers is to automate the entire process from test question generation to test paper generation by initiating the corresponding sc-agents (sc-agent for generating single type of test questions and sc-agent for generating a single test paper).

The function of the sc-agent for automatic scoring of test papers is to implement automatic verification of user answers to test questions and automatic scoring of test papers by initiating sc-agents for calculating the similarity between user answers and sc-agents for converting a logical formula into PNF.

VI. EVALUATING THE EFFECTIVENESS OF THE SUBSYSTEM

The effectiveness of the developed subsystem will be evaluated from the following aspects:

- availability of the generated test questions;
- difficulty level of the generated test papers;
- closeness between automatic scoring and manual scoring of user answers to subjective questions.

In order to evaluate the availability of the automatically generated test questions, 200 automatically generated test questions were randomly sampled from the tutoring system for discrete mathematics and the proportion of test questions that could be used directly was counted (Table I).

Table 1: TABLE. RESULTS OF THE EVALUATION OF THE AVAILABILITY OF THE GENERATED TEST QUESTIONS

Availability indicators	Test questions that can be used directly	Test questions that can be used after modification	Unavailable test questions
Number of test questions (total 200)	188	12	0
Proportion	94%	6	0

It can be seen from Table I that of the 200 automatically generated test questions sampled at random, 94% were able to be used directly and 6% were able to be used after modification.

The difficulty of the test paper is closely related to the user's score. Therefore, 40 second-year students were randomly selected to evaluate the difficulty of the test paper for discrete mathematics, which was automatically generated using the subsystem. 10 multiple-choice questions, 10 fill in the blank questions, 10 judgment questions, 2 definition explanation questions and 2 proof questions are included in this test paper. The maximum score for each objective question is 2 points, the maximum score for each subjective question is 10 points, and the maximum score for the whole test paper is 100 points (Table II).

From the Table II, it can be seen that the students' scores generally follow a normal distribution. Therefore, it can be concluded that the difficulty of the current type

Table 1: TABLE. STATISTICAL RESULTS OF STUDENT SCORES

Score	<40	[40-49]	[50-59]	[60-69]	[70-79]	[80-89]	≥ 90
Total number of students (40)	0	1	4	10	14	8	3
Proportion	0	2.5%	10%	25%	35%	20%	7.5%
Average score	72.85						

of test paper is moderate and that the actual knowledge level of the user can be checked objectively and fairly

In order to evaluate the closeness between the automatic scoring and manual scoring of user answers to the subjective questions, we decided to first enter the 40 students' answers to the subjective questions into the subsystem, then use the subsystem to automatically verify the students' answers, and finally count the error between the automatic scoring and manual scoring of user answers to the subjective questions (Table III).

Table 2: TABLE. RESULTS OF SCORING ERROR STATISTICS FOR USER ANSWERS TO SUBJECTIVE QUESTIONS

Error range (ф)	Definition explanation question 1	Definition explanation question 2	Proof question 1	Proof question 2	Total	Proportion
$\Phi \leq 1$	35	31	26	28	120	75%
(1-1.5]	2	4	8	8	22	13.75%
(1.5-2]	2	3	5	3	13	8.125%
$\Phi > 2$	2	3	5	3	13	8.125%

The formula for calculating the error Φ is shown below(4):

$$\Phi = |x - y| \quad (4)$$

The parameters are defined as shown below:

- x — is the manual scoring of user answers to the test questions;
- y — is the automatic scoring of user answers to the test questions;

From the Table III, it can be seen that the automatic scoring and manual scoring of user answers to subjective questions in the tutoring system for discrete mathematics generally remained consistent, and that when the maximum score for a subjective question was 10, the sample size with an error $\Phi \leq 1.5$ between scores was over 88%.

The above experimental results show that the developed subsystem can satisfy the conditions for practical applications.

VII. CONCLUSION

An automated approach to checking the knowledge level of users in tutoring systems developed using OSTIS Technology is proposed in this article. Based on the proposed approach, a universal subsystem for automatic generation of test questions and automatic verification of user answers is developed. Using the developed subsystem, the entire process can be automated from test question generation, test paper generation to automatic verification of user answers and automatic scoring of test papers.

Finally the effectiveness of the developed subsystem was evaluated in terms of the availability of the generated test questions, the difficulty of the generated test papers and the closeness between the automatic scoring and the manual scoring of the test questions in the discrete mathematics ostis-system. From the evaluation results, it can be seen that the developed subsystem can meet the conditions for practical application.

ACKNOWLEDGMENT

The work in this article was done with the support of research teams of the Department of Intelligent Information Technologies of Belarusian State University of Informatics and Radioelectronics. Authors would like to thank every researcher in the Department of Intelligent Information Technologies.

REFERENCES

[1] V. V. Golenkov and N. A. Guljakina, "Proekt otkrytoj semanticheskoj tehnologii komponentnogo proektirovanija intellektual'nyh sistem. chast' 1: Principy sozdanija project of open semantic technology for component design of intelligent systems. part 1: Creation principles]," Ontologija proektirovanija [Ontology of design], no. 1, pp. 42–64, 2014.

[2] V. Golenkov, N. Gulyakina, "Next-generation intelligent computer systems and technology of complex support of their life cycle," in Otkrytye semanticheskie tehnologii proektirovanija intellektual'nyh sistem [Open semantic technologies for intelligent systems], V. Golenkov, Ed., BSUIR. Minsk, BSUIR, 2022, pp. 27–40.

[3] D. Shunkevich, "Metodika komponentnogo proektirovaniya sistem, upravlyaemyh znaniyami," in Otkrytye semanticheskie tehnologii proektirovanija intellektual'nyh sistem [Open semantic technologies for intelligent systems], V. Golenkov, Ed., BSUIR. Minsk, BSUIR, 2015, pp. 93–110.

[4] D. Shunkevich, "Hybrid problem solvers of intelligent computer systems of a new generation," in Otkrytye semanticheskie tehnologii proektirovanija intellektual'nyh sistem [Open semantic technologies for intelligent systems], V. Golenkov, Ed., BSUIR. Minsk, BSUIR, 2022, pp. 119–144.

[5] (2023, Mar) Ims.ostis metasystem. [Online]. Available: https://ims.ostis.net

[6] Longwei. Qian, "Ontological Approach to the development of natural language interface for intelligent computer systems," in Otkrytye semanticheskie tehnologii proektirovanija intellektual'nyh sistem [Open semantic technologies for intelligent systems], V. Golenkov, Ed., BSUIR. Minsk, BSUIR, 2022, pp. 217–238.

[7] Wenzu. Li, "A semantics-based approach to automatic generation of test questions and automatic verification of user answers in the intelligent tutoring systems," in Otkrytye semanticheskie tehnologii proektirovanija intellektual'nyh sistem [Open semantic technologies for intelligent systems], V. Golenkov, Ed., BSUIR. Minsk, BSUIR, 2022, pp. 369–374.

[8] Li. W., Qian L. Semantic Approach to User Answer Verification in Intelligent Tutoring Systems. Communications in Computer and Information Science, 2022, Vol. 1625, pp. 242–266.

[9] Jiang. H., Zhao. Y., Li. X. Intelligent education system: A comprehensive review. IEEE Access, 2020, Vol. 8, pp. 201016-201026.

[10] Li. H. Research on item automatic generation based on DL and domain ontology. Journal of Changchun University of Technology (Natural Science Edition), 2012, Vol. 33(04), pp. 461-464.

[11] Kaur. M., Batra. S. Ontology-based question generation: a review. Journal of Intelligent and Fuzzy Systems, 2020, Vol. 39(01), pp. 49-57.

[12] Andreas. P., Konstantinos. K., Konstantinos. K. Automatic generation of multiple choice questions from domain ontologies. In: IADIS International Conference e-Learning, 2008, pp. 427-434.

[13] Arjun. S. B., Manas. K., Sujan. K. S. Automatic Generation of Multiple Choice Questions Using Wikipedia. International Conference on Pattern Recognition and Machine Intelligence, 2013, Vol. 8251, pp. 733-738.

[14] Chen. C. H. A comprehensive survey of text similarity measures. Journal of Information Science, 2019, Vol. 45(01), pp. 1-19.

[15] Singh. A., Singh. V. K. Text similarity techniques: a systematic literature review. International Journal of Computer Applications, 2019, Vol. 182(41), pp. 23-30.

[16] Baly. R., Jansen. P., De. Rijke. M. A review of evaluation methodologies in automatic short answer grading. Educational Research Review, 2014, Vol. 13, pp. 20-33.

[17] Kim. Y., Kwon. O. N., Kim. Y. Automatic short answer grading using latent semantic analysis with fuzzy matching. Journal of Educational Technology and Society, 2016, Vol. 19(03), pp. 257-269.

[18] Mingyu. Ji., Xinhai. Zhang. A Short Text Similarity Calculation Method Combining Semantic and Headword Attention Mechanism. Scientific Programming, 2022.

[19] Anderson. P., Fernando. B., Johnson. M., Gould. S. Spice: Semantic propositional image caption evaluation. In: European Conference on Computer Vision, Springer, 2016, pp. 382-398.

[20] Shu. X., Wang. S., Guo. L., Zhao. Y. Survey on multisource information fusion: progress and challenges. Information Fusion, 2018, Vol. 42, pp. 146-169.

[21] Wang. X. Y., Hu. Z. W., Bai. R. J., et al. Review on Concepts, Processes, Tools and Methods Ontology Integration. Library and Information Service, 2011, Vol. 55(16), pp. 119-125.

[22] Liu. J., Liu. Y., Wang. X., Wang. B. A survey on ontology integration techniques. Future Generation Computer Systems, 2020, Vol. 105, pp. 17-30.

[23] Fujiwara. M., Kurahashi. T. Prenex normal form theorems in semi-classical arithmetic. The Journal of Symbolic Logic, 2022, pp. 1-31.

[24] Pan. M., Ding. Z. A simple method for solving prenex disjunction (conjunction) normal forms. Computer Engineering and Science, 2008, Vol. 30(10), pp. 82-84.

[25] Ge. L., Li. X. An overview of the methods for automated theorem proving in geometry. Journal of Symbolic Computation, 2016, Vol. 74, pp. 303-335.

[26] Kryakin. A., Nguyen. P. Automated theorem proving in geometry using Grobner bases. Journal of Automated Reasoning, 2014, Vol. ¨ 53(02), pp. 163-189.

[27] Reiter. R. A Logic for Default Reasoning. Artificial Intelligence, 1980, Vol. 13(1-2), pp. 81-132.

[28] Chou. S. C., Gao. X. S., Zhang. J. Machine Proofs in Geometry: Automated Production of Readable Proofs for Geometry Theorems. World Scientific, 1994.

Автоматизированный подход к проверке уровня знаний пользователей в интеллектуальных обучающих системах

Ли Вэньцзу

Данная работа посвящена проблеме автоматизации реализации быстрого тестирования знаний пользователей в интеллектуальных обучающих системах нового поколения. В данной работе подробно описывается основанный на семантике подход к автоматизации всего процесса от генерации тестовых вопросов и экзаменационных билетов до автоматической проверки ответов пользователей и автоматической оценки экзаменационных билетов.

На протяжении многих лет педагоги активно высказывают желание использовать компьютеры для автоматизации обучения и преподавания. С развитием технологии искусственного интеллекта в последние годы, это желание может наконец-то стать реальностью. Наиболее представительным продуктом, объединяющим искусственный интеллект и образование, являются интеллектуальные обучающие системы (ИОС), которые могут не только значительно повысить эффективность обучения пользователей, но и обеспечить справедливость и беспристрастность образовательного процесса.

Автоматическая генерация тестовых вопросов и автоматическая проверка ответов пользователей являются самыми основными и важными функциями ИОС. Использование этих двух функций в комбинации позволит реализовать весь процесс от автоматической генерации тестовых вопросов до автоматической оценки экзаменационных билетов пользователей. Это не только значительно сократит повторяющуюся работу педагогов, но и снизит стоимость обучения для пользователей, что позволит большему числу людей получить доступ к различным знаниям.

Хотя в последние годы благодаря развитию таких технологий, как семантические сети, глубокое обучение и обработка естественного языка (NLP), было предложено несколько подходов для автоматической генерации тестовых вопросов и проверки ответов пользователей, эти методы все еще имеют следующие основные недостатки:

- существующие подходы к генерации тестовых вопросов позволяют генерировать толькj самые простые объективные вопросы;
- некоторые из существующих подходов (например, сопоставление ключевых слов и использование статистической вероятности) для проверки ответов пользователей на субъективные вопросы не учитывают семантическое сходство между ответами;
- методы, использующие семантику для проверки ответов пользователей на субъективные вопросы, могут вычислять сходство только между ответами с простыми семантическими структурами;
- и т.д.

Поэтому на основе существующих методов и Технологии OSTIS в данной работе предлагается подход к разработке универсальной подсистемы для автоматической генерации тестовых вопросов и автоматической проверки ответов пользователя в обучающих системах, разработанных с использованием Технологии OSTIS (открытая семантическая технология проектирования интеллектуальных систем).

Received 29.03.2023