Embedded Selforganizing Systems

Special Issue: "Learner Centered Learning (LCL 2026)" 5th International Workshop

Optimization of Assessment Tools for Course Syllabi Based on a CRM Model and a Genetic Algorithm

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***Abstract*— This paper proposes a genetic algorithm method for optimizing assessment tool funds (ASTF) in Economics based on the CRM model to fully cover competency requirements with ASTF elements. The relevance of this study lies in the growing number of experts working in the development and use of higher education training standards noting the transformation of the higher education paradigm in the current context. The scientific novelty of this study lies in the fact that it bridges the research gap in addressing the optimization of processes for fully covering competency requirements with ASTF elements. The practical significance is that this method will be widely applied in practice, and, in the future, the development of the educational process will experience a transformative nature based on the use of a combination of GitHub and AI.**

Keywords—optimization of assessment tools, artificial intelligence, competencies, genetic algorithms, transformation of the higher education paradigm

I. INTRODUCTION (*HEADING 1*)

The development of higher education in today's environment is characterized by a shift toward flexible, adaptive, and effective models of educational management. Methods based on Competency-Based Role Models (CRMs) are increasingly being used, particularly in training high-intelligence programmers. Given the widespread digitalization of the economy and the stringent labor market demands on graduates, especially those in strong AI, traditional approaches to developing Assessment Tool Funds (ATFs) are no longer feasible. Experience has shown that this problem is particularly acute in undergraduate programs in Strong AI/AGI, where the interdisciplinary stack requires not only deep technical knowledge but also professional economic thinking.

"Economics," for senior IT students, is being transformed and becoming a more applied discipline. It enables the use of a vast number of new methods, such as: 1) assessing the cost of end-to-end technologies, 2) calculating the total cost of ownership (TCO) based on the utilization of computing clusters, 3) forecasting the return on investment (ROI) of AI infrastructure, and 4) designing the unit economics of intelligent agents.

Ensuring end-to-end, objective, and non-redundant coverage of CRM competencies by FOS elements within this discipline is a multi-criteria optimization problem of high computational complexity (NP-hard).

This paper is devoted to the theoretical and methodological justification, mathematical formalization, and practical implementation of Genetic Algorithms (GA).

GA and other artificial intelligence methods are used for the automated synthesis of optimal FOS in the context of the implementation of state programs and strategic guidelines of the Russian Federation.

The relevance of using Genetic Algorithms and artificial intelligence methods to optimize FOS within the framework of CRM models of universities is determined by three key factors. Firstly, strategic government procurement. Secondly, the institutional transformation of higher education. Thirdly, the specifics of training highly qualified personnel for the strong AI industry.

The aim of the study was to optimize the coverage of competency requirements within the competency-based role model (CRM) using the genetic algorithm (GA) method.

The practical significance of the study lies in its potential for practical application and is manifested in the creation of specific digital tools for managing the quality of education, optimizing the labor costs of educational process participants, and enhancing the competitiveness of graduates.

The development of next-generation educational programs is being carried out in accordance with the National Strategy for the Development of Artificial Intelligence through 2030, approved by the Decree of the President of the Russian Federation.

Furthermore, the Federal Project "Artificial Intelligence" is being implemented within the framework of the national program "Digital Economy of the Russian Federation." According to these documents, a key factor in achieving the country's technological sovereignty is providing the industry with personnel possessing world-class competencies in the development and implementation of AI solutions.

The State Program "Scientific and Technological Development of the Russian Federation" [1] and the strategic project "Priority 2030" [2] require leading universities to fundamentally restructure their educational models, transition to individualized educational trajectories, and implement intelligent learning management systems (AI-driven LMS).

The development of AI is reflected in the Presidential Decree [3]. Experts note that over the past six years, approximately 1,500 patents for AI-based developments have been registered in Russia, with their number growing by more than 50% in the past year and a half alone [4]. The Law "On Supporting the Development of Artificial Intelligence Technologies" defines AI and large fundamental models, and lists four key principles: 1) technological independence; 2) respect for human rights and freedoms; 3) respect for traditional spiritual and moral values; 4) security [5].

II. Material and Methods

The following research methods were used in the article: theoretical, analytical, genetic algorithm, competency-role model, AI agent in the GitHub service, bipartite directed graph, which allowed us to formalize the problem of optimizing competency coverage in terms of graph theory and matrix analysis.

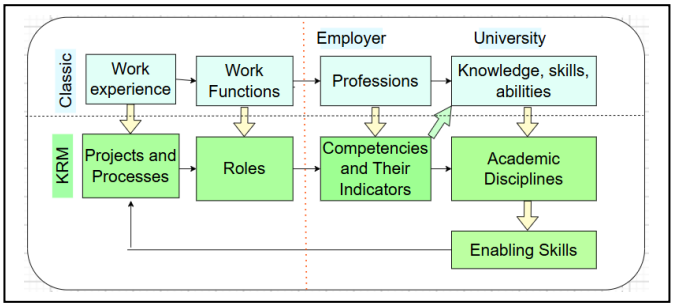
III. Results and Discussion

A. Development of the CRM model

With the rapid development of artificial intelligence (AI), the need to develop a competency-based role model for specialists in this field has become particularly pressing. Therefore, the AI competency-based role model facilitates the integration of education and professional activity, as well as a common language for communication.

Klimov A.S. and Bukhanovsky A.V. with colleagues proposed a new concept of the Competency-Role Model [15] (Figure 1).

Several models are known: 1) the Universal Competency Model; 2) the Alliance's Basic Model of Professions and Competencies in AI; 3) the ITMO Public Competency-Role Model; 4) the Competency-Role Model for ITMO's Top-Level Programs of the Ministry of Digital Development,



Communications, and Mass Media. A professional role is a set of positions (job titles) and responsibilities that defines the specialist's place and functions (tasks) within their professional activities.

Fig. 1. Professional roles are at the core of the CRM model

These can be briefly described as follows:

1) the Ministry of Education and Science's Universal Competency Model in AI (2021), which attempted to describe AI training using traditional educational process models.

2) the Alliance's Basic Model of Professions and Competencies in AI (2021, 2024), which systematizes the content and comprehensiveness of AI academic disciplines from an employer perspective.

3) the ITMO Public Competency-Role Model (2023), which described the educational process to cover effective combinations of professional roles.

4) A competency-based role model for top-level programs of the Ministry of Digital Development (2025), developed by ITMO staff under the leadership of A.V. Bukhanovsky (commissioned by the Analytical Center under the Government of the Russian Federation), represents a flexible and universal constructor of measurable educational processes in AI, taking into account rapid changes in technology and the labor market.

The competency-role model provides a systematic description of the key professional competencies required for the successful performance of top specialists in the field of artificial intelligence. It addresses a direct problem: defining the professional profile of a graduate of a specific educational program.

In other words, it addresses the inverse problem: designing the composition and content of the educational program's disciplines to create the required profile of a graduate prepared to work in a particular professional field. A professional field, in this case, represents the set of tasks, functions, responsibilities, and types of work performed by a specialist within a specific field, industry, or area, where specific knowledge, skills, technologies, methods, and standards are applied.

The following can help describe the requirements for a graduate's profile: the labor market (by analogy); foresight; an industrial partner; and the student themselves. Technology

readiness levels assess the maturity of a technology at the conceptualization, development, and application stages on a scale of one to nine. One is the lowest level, and nine is the highest. There are several levels of training for AI specialists.

TOP-DS* (Top Data Science) - Theoretical researchers capable of working at the frontier and gaining new fundamental knowledge in AI and related fields. UGT 1-4, result: A* articles.

TOP-DS program - Applied researchers and developers of fundamentally new science-intensive solutions in AI. UGT 3-7, result: AI frameworks.

Developing a graduate model for the UCT in the field of AI is crucial. For faculty, the implementation of the developed AI model allows them to automate the most routine and error-prone part of course design—the creation of assessment materials. Senior faculty receive a scientifically validated FOS configurator. Instead of manually compiling options, professors upload a common bank of developed assignments (cases, tests, projects) with their characteristics into the system, and the algorithm generates an optimal, balanced assessment curriculum in seconds, reducing the instructor's time spent on course design by 40–60%.

DS program - Creative engineers capable of effectively creating applied AI systems based on the latest technologies. UGT 5-9, result: applied AI system.

The final model contains 56 professional and advanced competencies, including three universal and 25 industry-specific ones. Each competency is associated with several indicators with three levels of development: basic, intermediate, and advanced.

A list of recommended topics for developing educational disciplines is also included, as is a list of references and practical case examples with three difficulty levels: for practical, laboratory, and coursework assignments, as well as practical skills assessments. The resulting matrix maps professional roles to specific sets of competencies with varying levels of development (Table 1).

TABLE I. PROFESSIONAL ROLES IN AI

Roles	Purpose
AICDO (Head of Digital Transformation)	Designing new ways to create value within the organization through the application of AI
AI Architect	Designing the architecture of AI systems
AIPM (AI Manager)	Managing the AI solution development process
ML Researcher (Machine Learning)	Generating new fundamental knowledge, new machine learning algorithms
MLE (Machine Learning Engineer)	Practical implementation and implementation of ML models
Data Analyst	Knowledge and data extraction
Data Architect	Designing data architecture within an organization
Data Engineer	Creating and maintaining a data collection and processing infrastructure
TADS (Technical Data Analyst)	Technical implementation of data storage and processing procedures
AI Security Engineer	Ensuring the security, reliability, and ethics of AI systems
AI Operations Specialist	Automation and lifecycle management of ML models

For undergraduate students (Strong AI track), the proposed development is valuable because it provides them with a transparent, redundant assessment pathway.

Eliminating duplicate and ineffective assessment elements reduces academic burnout among senior students, allowing them to focus on deeply solving key interdisciplinary cases (e.g., the economic design of a distributed infrastructure for training generative models).

The objectivity of assessment is enhanced, as the GA ensures that each assignment in the assessment framework is strictly linked to a specific measurable learning outcome in the CRM.

The proposed approach is important for university management and quality assurance. At the level of university management and educational program directorates, the implementation of AI models for assessment framework optimization ensures complete digital transparency of curricula compliance with the requirements of the Federal State Educational Standards of Higher Education, professional standards, and internal CRM. The model provides a digital discipline passport that mathematically demonstrates the complete coverage of the stated competencies, which is critical for national and international accreditation procedures, as well as for the audit of educational programs by industrial partners in the IT sector.

To prepare AI specialists of the required level, ITMO experts presented the following competency domains (Figure 2).

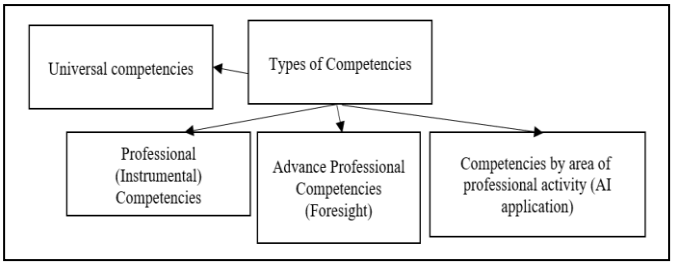


Fig. 2. Types (domains) of competencies proposed by ITMO

The FOS doesn't need to be a separate standardized document; it can be a visual and convenient Git repository.

What types of KIM are there:

- Lists of questions (a) multiple-choice, (b) open-ended (+ criteria);
- Lists of topics for colloquiums + criteria;
- Lists of topics for papers, essays, and other independent written work + criteria;
- Lists of topics for independent study and discussion at seminars + criteria;
- Computer-based laboratory work;
- Assignments for coursework + criteria;
- Assignments for student research projects + criteria;
- Assignments for practical training (usually developed with individual entrepreneurs) + criteria;
- Assignments for a qualifying work (diploma) + criteria;
- Exam and test tickets;

- Other types of assignments (business games, AI simulators, etc.).

The main element of the FOS is the measurement model (Table 2).

When developing a CRM model, problems typically arise during the development of the FOS, where the dilemma arises as to which tools to use to ensure full coverage of competency requirements without exceeding the labor intensity or compromising the diversity of testing tools. The KMI (competency indicator level of mastery) approach comes to the rescue.

TABLE II. MODEL FOR MEASURING THE ASSESSING FUNDS (FRAGMENT)

Element	Competence	Indicator	Level	Descriptor of mastery
Module 1	LLM1	1.1-1.2	C	Boundary
Lesson 1.1	-	-	B	Current
Lesson 1.2	-	-	C	Current
Module 2	LLM2	2.1	B	Boundary
…	…	…	…	…
Exam	-	-	-	Midterm
Additional forms (for poor students)	-	-	-	Midterm
Final assessment	LLM1	-	-	Final assessment

New professional competencies in the AI CRM are presented in Table 3.

TABLE III. NEW PROFESSIONAL COMPETENCIES IN THE AI CRM FOR THE ECONOMY

Area	Direction	Name Competency
AI Systems Life Cycle	AI Economics	Capable of assessing and predicting the economic and social impact of AI implementation in a specific organization

A competency-based learning outcome (CBO) is the fundamental unit of decomposition in a competency-based learning model (CBM), which captures not just a general competency but also its measurable outcome (through indicators) and a specific level of mastery. It is at this level that a university formulates and describes an educational program, selecting the necessary CBOs to achieve the specified learning outcomes.

As is well known, assessment is a process of evaluating the professional qualities of employees and candidates, which allows for the identification of their strengths and weaknesses, as well as their level of skills and competencies. It is used to determine the ability to perform specific tasks and predict performance in a specific position. Assessment can include various methods and tools, such as tests, interviews, and group assignments, and is often used in business to evaluate current staff and candidates for management positions. A CBO defines a target measurable unit of learning outcome, and it is for this unit that assessment tasks are selected to verify whether the required level of mastery of a specific competency has been achieved. This is directly consistent with the logic of the competency-based performance model (CBM).

B. Genetic Algorithm for Optimizing the Assessment Tools Fund of the Competency-Role Model

A CBO defines a target measurable unit of learning outcome, and it is for this unit that assessment tasks are selected to verify whether the required level of mastery of a specific competency has been achieved. This is directly consistent with the logic of the competency-based performance model (CBM).

Integrating GA with educational data mining methods is crucial. Architecture of a GA model for optimizing the coverage of the CRM.

Optimizing the coverage of the educational task map with educational data mining elements using GA

Within the framework of integrated artificial intelligence systems at universities, GA is not an isolated tool, but the core of an intelligent ecosystem. The novelty lies in the synergy of GA with predictive analytics methods: task difficulty parameters and their actual cost (completion time) are dynamically adjusted based on the analysis of digital traces of students from previous years of study using neural network models or decision trees. This transforms the static educational task map into a self-learning, adaptive model.

The objective function (minimization problem) will take the form:

$$\text{Target(X)} = \sum_{i=1}^{n} x_i * w_i + \lambda * \sum_{j=1}^{m} \max(0.1 - \sum_{i=1}^{n} x_i * A_{ij}) \rightarrow \min, \quad (7)$$

Where λ is the penalty coefficient for not covering a competency indicator ($\lambda \gg \max(w_i)$).

The second term of the equation is equal to zero if and only if each CRM indicator is covered by at least one selected FOS element. A genetic algorithm (GA) for optimizing competency coverage by elements of the assessment toolbox (AST) within a learning outcomes map/competency model (LEM) is a discrete optimization problem.

The goal of the model is to select a minimal and sufficient set of assessment tasks that completely covers all competency achievement indicators, taking into account difficulty weights and levels according to Bloom's taxonomy. GA model architecture and parameters. Chromosome (individual): A binary vector of length N, where N is the total number of available tasks in the FOS database. A value of 1 means that the task is included in the final set, 0 means it is excluded.

Fitness Function: A penalty function that takes into account the completeness of competency matrix coverage, redundancy (minimizing the total number of tasks), and the diversity of mastery levels. Genetic operators: One-point or two-point crossover, inverse mutation to avoid local optima. Optimization of the coverage of the CRM by FOS elements using a GA is presented below (Figure 3).

Fig. 3. Active matrix of the FOS and coating of the CRM

Genetic Algorithm Structure:

1. Encoding: A chromosome is a bit string of length n.
2. Initialization: An initial population of size P is created by randomly generating bit strings.
3. Selection: Tournament selection (tournament size k=3) is used to ensure high selective redundancy and the preservation of leading genotypes.
4. Crossover: A single-point crossover operator performed with a given probability $P_m \in [0.7,0.9]$.
5. Mutation: A weak bit inversion $P_m \in [0.05,0.2]$ prevents premature convergence of the population to a local extremum.

Parameter ax3-a histogram of FOS frequencies. It dynamically shows which FOSs "survive" in the population from generation to generation. It shows how the GA discards unnecessary FOSs (for example, the expensive FOS-3) and retains the minimum set.

The model uses the ax4 parameter – the "BEFORE/AFTER" comparison panel. The top row is a static initial random solution; the bottom row is animated in real time as the GA runs. It is clearly visible how the coverage "checkmarks" appear one after another, and the cost decreases (Figure 4).

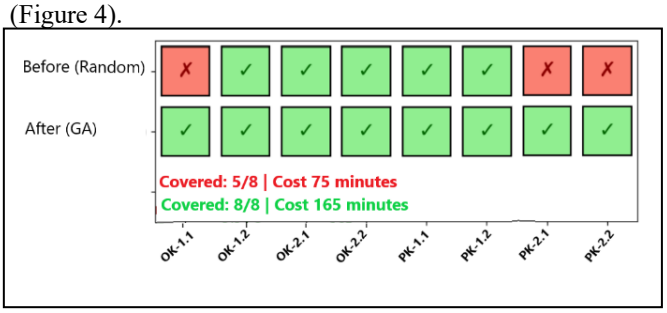


Fig. 4. Clearly showing how the coverage "checkmarks" appear one after another

Separating fitness and cost allows the net cost (without the 1000 penalty for uncovered indicators) to be displayed on the convergence graph, making the dynamics understandable. The penalty is used only within the GA for selection.

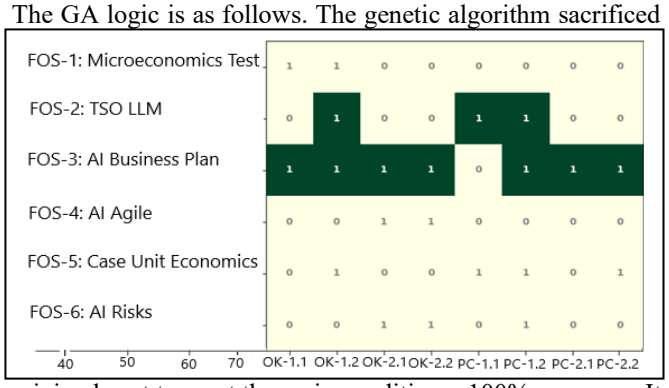
Optimization results: a comparison "before" and "after" the GA is as follows. Before optimization (initial random solution): selected FOS (2): FOS-2: case: TCO LLM; FOS-6: AI agent risks; total cost: 75 minutes; indicator coverage: 5/8 (there are gaps).

After optimization (GA solution, generation 60): selected FOS (2): FOS-2: case: TCO LLM; FOS-3: AI business plan; total cost: 165 minutes; indicator coverage: 8/8 (100%).

Performance Analysis: Coverage: +3 indicators (full coverage of the CRM achieved); Cost: +90 min (optimal costs to guarantee 100% results); Fitness function: decreased from 3075 to 165 (penalties for uncovered competencies eliminated).

Here are some important clarifications. Cost paradox: the cost increased by 90 minutes (from 75 to 165), but this is not a bug, but a demonstration of the algorithm's performance. The random set was cheap, but did not solve the problem, since three indicators remained uncovered, resulting in a huge penalty of +3000 to the fitness function.

The GA logic is as follows. The genetic algorithm sacrificed



minimal cost to meet the main condition—100% coverage. It replaced the cheap but narrow "FOS-6" with the more expensive but capacious "FOS-3," which filled all the remaining gaps.

IV. Experiments and Discussion

Results of a computational experiment and convergence analysis. As part of the testing of the developed AI model, a simulation was conducted to optimize the fitness function for the Economics course for senior undergraduate students studying strong artificial intelligence systems development. The experiment utilized real-world performance indicators (including LLM TCO assessment, unit economics of AI agents, and risk management of autonomous systems).

The fitness function exhibited a certain dynamic. Its decline from 3075 to 165 is the primary evidence of the optimization's success. The algorithm found the mathematically cheapest way to achieve full coverage without penalties.

Research indicates that artificial intelligence is increasingly being applied in all areas of human activity. The authors are discovering important and effective solutions to complex problems.

For example, a team of authors led by V.A. Yemelyanov developed a recommender system for assessing metal properties based on a neural network [16].

Looking ahead, further research is expected in the following areas.

Author Myint Swe Khine notes that modern advances in artificial intelligence (AI) provide educators with flexible solutions, such as adaptive learning and assessment, that personalize the learning process for students. Using machine learning algorithms and data analysis, AI personalizes students' learning paths and optimizes outcomes [17].

Adiyono Mahyudin Ritonga and their co-authors found that artificial intelligence (AI) is revolutionizing higher education by enabling personalized learning and adaptive assessment. AI-powered personalized learning tailors educational content to each student, increasing engagement and improving learning outcomes [18].

V. Conclusions

The use of artificial intelligence methods, particularly genetic algorithms, to optimize educational models for CRM and FOS in higher education institutions represents a breakthrough in both scientific and practical research. The implementation of such systems directly addresses the challenges of the Russian Federation's state policy in building a digital economy and achieving full technological sovereignty in IT and Strong AI. The developed and verified approach allows for the transition of course design from an empirical level to rigorous mathematical optimization. This ensures the guaranteed quality of undergraduate training through the complete closure of competency matrices, minimizes the time spent by senior faculty, and optimizes the cognitive load on students. Among some important results, a cost paradox should be noted: the cost increased by 90 minutes (from 75 to 165), but this is not an error, but a demonstration of the algorithm's operation. The random set was inexpensive, but it didn't solve the problem because three indicators remained uncovered, inflicting a huge penalty of +3000 on the fitness function. The genetic algorithm sacrificed the minimum cost to meet the key requirement—100% coverage. It replaced the inexpensive but narrow "FOS-6" with the more expensive but capacious "FOS-3," which filled all the remaining gaps. The fitness function acquired a certain dynamic. Its drop from 3075 to 165 is the main proof of the optimization's success. The algorithm found the mathematically cheapest way to achieve full coverage without penalties. Prospects for further research lie in the integration of genetic algorithms with multi-agent systems and deep neural networks for dynamically rebuilding the FOS in real time based on changing IT industry requirements and individual student performance.

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