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# Application of Evolutionary-Oriented Methods for Designing Interdisciplinary Educational Programs

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***Abstract.*** *The construction of a multidisciplinary educational program is a multi-step process, since it reflects the dynamics of a student's learning and should allow timely adjustments to the learning process. In this regard, the purpose of the article is to determine the required method and its adaptation for the design of multidisciplinary educational programs (EP). This article discusses the application of the method to merge two or more educational programs in the design of multidisciplinary educational programs. In general, the work of the genetic algorithm is presented in the form of a block diagram. The characteristics of the evolutionary genetic algorithm and the projection of the genetic algorithm on the design of interdisciplinary educational programs are described. A multicriteria approach to assessing the quality of the working curriculum is presented: an assessment of the proximity of dependent disciplines, an assessment of the uniformity of knowledge development. The article deals with the normalization of private estimates and the construction of a generalizing criterion.*

***Keywords:*** *EP design, educational program, evolutionary genetic algorithm, multidisciplinary educational program.*

**Introduction**

Modern requirements for the quality of education are directly related to the need to achieve results in priority areas of development of science, technology and technology. It is known that scientific and technological breakthroughs occur, as a rule, at the intersections of sciences, as a result of comprehensive research of objects and related problems [1]. At the same time, interdisciplinary research is understood as a comprehensive study of a single research subject by representatives of various scientific disciplines. Interdisciplinarity can be viewed as a form of organizing scientific knowledge based on certain links between scientific disciplines (areas of knowledge), methods and technologies that provide a solution to complex scientific and technical problems [2]. Multidisciplinarity is characterized by the properties of integrative disciplines based on the transfer of research methods from one discipline to another, and requires a synthesis of the results obtained within various scientific disciplines.

In the system of higher and postgraduate education, the formation of graduates' competencies in various fields of knowledge related to the implementation of interdisciplinary research is provided by interdisciplinary educational programs [3-4]. The main feature of the multidisciplinary nature of educational programs is the breadth of training. The multidisciplinarity of the implemented HVE educational programs is based on established integrated scientific areas that have arisen at the intersection of sciences (for example, specialties 020208 «Biophysics», 020208 «Biochemistry», direction 020900 «Chemistry, Physics and Mechanics of Materials», etc.). However, at present, Kazakhstani universities produce mainly narrow specialists in specific areas of professional knowledge who do not have a sufficient range of competencies for effective scientific and innovative activities in the framework of strategically important directions for the development of science and technology.

In the conditions of academic freedom of universities, the quality of training specialists directly depends on the relevance of educational programs [5]. At the same time, the professional competencies of future specialists should be formed in accordance with the needs of the labor market in specific regions of the republic. When developing multidisciplinary educational programs, identifying a set of disciplines that correspond to the competencies presented is one of the main tasks of educational organizations. However, there are no software applications of this kind on the market that allow you to design and form multidisciplinary educational programs in an automated form [6]. The construction of a multidisciplinary educational program is a multi-step process, since it reflects the dynamics of a student's learning and should allow timely adjustments to the learning process.

In this regard, the design of multidisciplinary educational programs (EP) becomes an urgent task, namely, the application of methods for merging two or more educational programs [7].

It should be noted that the content and development of educational programs determines the quality of the educational services provided, in particular, the level of competencies that a graduate will have upon completion of the program.

**Evolutionary Oriented Methods**

Methods based on the evolutionary process of selection of living organisms are very popular. At the same time, the most popular are the methods of the genetic algorithm (hereinafter GA), which are related to the type of probabilistic approximate optimization methods when using the iterative search solution. The main advantage of GA is to obtain the desired solution in a short period of time of large dimension, for which the use of exact and approximate deterministic methods is not possible.

In such an algorithm, including other optimization methods, the «solution» is of prime importance, where «solution» is understood as the admissible structure of the object being optimized (individual / chromosome).

In GA, the process is identical to the ideas of natural selection and genetics, that is, the process of evolutionary selection with elements of mutation is repeated, where individuals of a new species are more adapted (adapted) to survive in the current habitat. In classical optimization theory, habitat refers to the term feasible solution area, and the term adaptability to fitness function.

Optimization in this case is iterative, where each cycle is called a generation. GA operates with a finite set of solutions, called a population. In GA theory, a population is formed from feasible solutions of objects.

By analogy with wildlife, GA starts from the initial population, the individuals of which, under the influence of external factors in limited conditions and in a competitive environment, change their properties at the genetic level. Further, the process of crossing occurs, where the offspring inherits the combined properties of their parents, and they are called offspring, they are also part of the population. In addition, at a certain point in time, a mutation of individuals occurs, whose genes undergo random changes, acquiring new properties. In such a chain, as a result, there is a competition for the right to enter the next generation – natural selection. At the same time, individuals with a higher adaptability to the external environment have the greatest chances.

The practice and results of applying this algorithm have been proven by other scientists, which made it possible to apply GA to address the issue of interdisciplinary relationships.

**Characteristics of the evolutionary genetic algorithm. GA projection for the design of interdisciplinary educational programs**

In general, the work of the genetic algorithm can be presented in the form of a block diagram shown in Figure 1. It is proposed to consider the stages of the GA work with further projection on the design procedure of interdisciplinary educational programs. First, you need to define terms from evolutionary selection:

A gene is the minimum real value that has the hereditary properties of an individual / object. In our

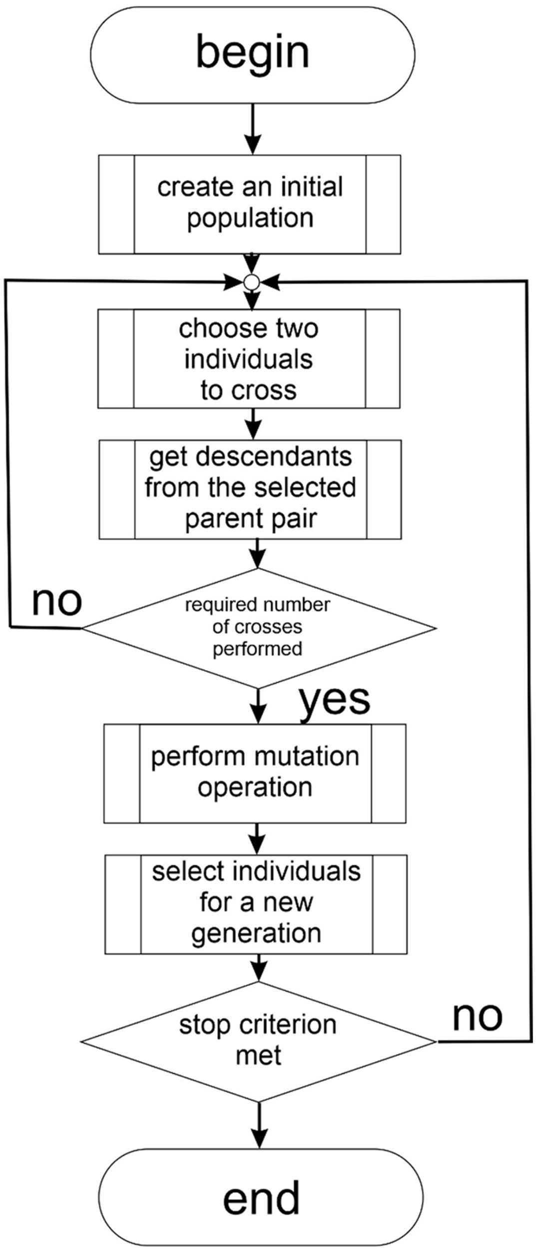


Figure 1 – Block diagram of the genetic algorithm

case, the genome will be the discipline defined in the i-th semester. The object / individual is the formed working curriculum.

An allele is one of the variants of the same gene, and only one of the variants can be present on the chromosome. In the case of projection, we are talking about the same discipline, but with a different description.

Heredity is the property of objects / individuals to pass on from generation to generation the properties of parents through genes. Educational programs obtained after GA operations retain the properties of their ancestors, that is, the original educational programs.

The procedure in evolutionary GA takes place in a space consisting of a set R of admissible values. The search process occurs by selecting individuals from the presented set R, the generated representation is denoted by R*, which is chosen so that the search algorithm can more easily interact with objects from the R* representation. The mapping of R objects to R* elements defines the relationship between optimized objects and relationships. This rule of converting objects representing their R to R* is called encoding.

GA works with individuals grouped into one species. Moreover, each individual / object is a concatenation of genes (the operation of combining two or more objects into one). In comparison with the process of evolution, a gene takes on the values of a certain allowed set and represents a unit of heredity of an object, which is passed on to descendants, thus preserving the characteristics of the parent.

**Genetic Algorithm Methods**

The main function in the genetic algorithm is the process of crossing (crossing over). The main feature of this process is the accumulation in the offspring of the best traits that the parent had. Crossing over consists in the formation of a new educational program, which turned out in the process of merging two or more educational programs through the exchange of disciplines, that is, fragments of a chromosome. Thus, a new descendant is formed in the process of merging, which retains the properties of its parents, receiving only the best qualities from them. At the moment, there are several types of crossing over:

- single point: a region between genes is selected, which is called a break point, and both parental pair are broken into two segments at the break point. After that, in places of rupture, they are combined with discontinuous segments (Figure 2a).

- two-point crossing over: a site between the genes is selected and two break points are selected, and in this case the resulting segments are swapped and glued together (Figure 2b).

- uniform crossing over: in this variation, each gene is inherited by descendants with a given probability, that is, according to a pre-formed gene mask.

After the formation of a new generation obtained in the process of mutation or crossing over, the question of choosing objects that will continue to form a new generation is being decided.

There are several ways to select objects:

- proportional selection: selection is based on the ratio of the value of its fitness function to the arithmetic mean of this function throughout the population;

- tournament selection: N objects are randomly selected, in which the probability of passing to the next round is directly proportional to the degree of

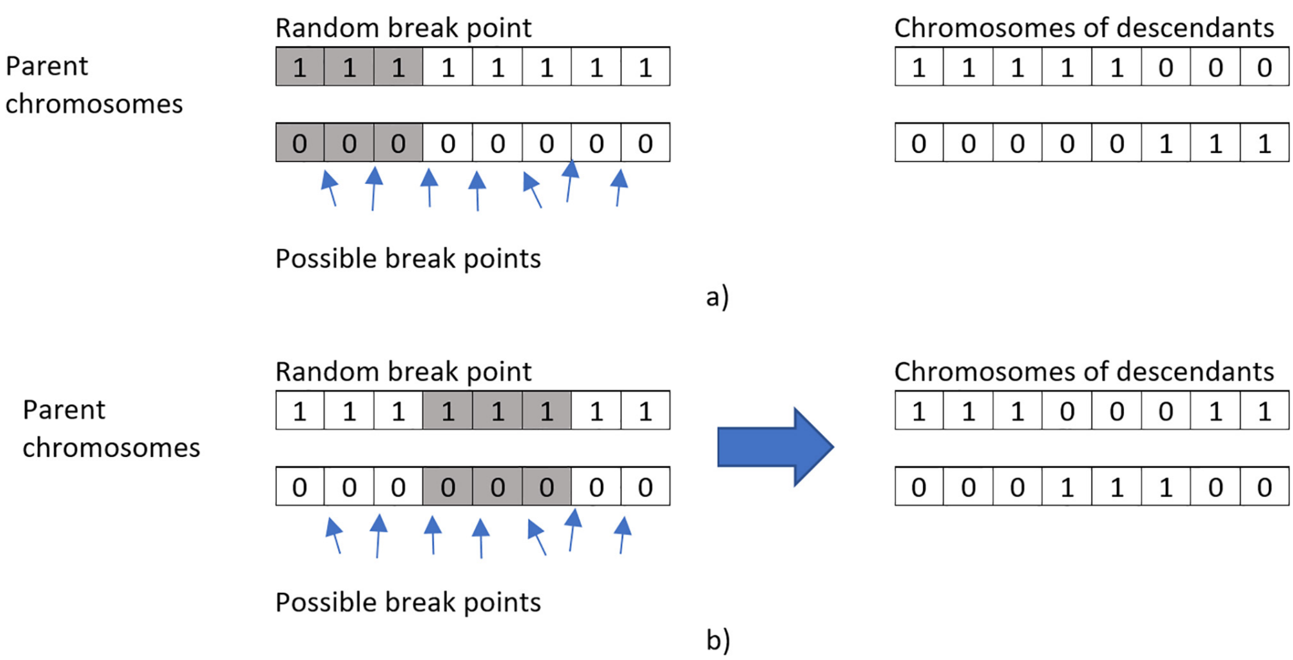


Figure 2 – Crossing over

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Individual $G^x$ | $g_1^x$ | $g_2^x$ | $g_3^x$ | $g_4^x$ | $g_5^x$ | $g_6^x$ | $g_7^x$ |
| Individual $G^y$ | $g_1^y$ | $g_2^y$ | $g_3^y$ | $g_4^y$ | $g_5^y$ | $g_6^y$ | $g_7^y$ |
| Mask | 1 | 1 | 2 | 1 | 2 | 1 | 2 |
| Descendant | $g_1^x$ | $g_2^x$ | $g_3^y$ | $g_4^x$ | $g_5^y$ | $g_6^x$ | $g_7^y$ |

**Figure 3 – Uniform crossing over**

its fitness;

- selection by truncation: sorting is performed in descending order of the values of fitness functions, in the list of which objects that have not reached the fitness threshold are cut off.

Thus, an evolutionary process takes place, in which the offspring changes their structure to enhance their fitness function.

**Multi-criteria approach to assessing the quality of the working curriculum**

*General characteristics of the approach*

The working curriculum is a complex structure and, accordingly, for a correct assessment of the quality of EP, it is necessary to use a multi-criteria approach, which will take into account the requirements prescribed in the state compulsory education standards, as well as meet the expectations of employers in the preparation of students. We will use the vector format to build a multicriteria strategy, that is, we will characterize certain requirements by private estimates and subsequently derive a vector criterion. One of the features of this approach is the need for the correct form of constructing the vector norm, that is, the criterion for optimizing the working curriculum.

Separate criteria will be considered in the form of a penalty function for non-compliance with the norms prescribed in the state compulsory education standards and other indicators, and we consider optimization from the standpoint of minimizing the norm of the components of the general vector criterion.

Today, there are different ways of constructing the norm of a vector criterion, however, it is proposed to use the minimax method, which is most suitable for the specified algorithm. Optimization with this approach is carried out according to the principle of minimizing the maximum of the values of the vector criterion [8-10]. The minimax approach can be formalized as follows:

$$|K| = \max_{i=1\ldots n}\{K_i\} \to \min,$$

Where $K_i$ – value of a particular criterion $i$; $n$ – number of private criteria.

*Assessment of the uniformity of knowledge development*

The most meaningful assessment of the uniformity of the distribution of the teaching load by semester is the standard deviation of the number of classroom lessons from their average value for all semesters of the curriculum. Let $h_s$ – be the number of academic credits assigned in semester $s$, and $\bar{h} = \frac{1}{n}\sum_{s=1}^{n} h_s$ – is the average value of $h_s$ for the term of study. Then the standard deviation of the number of classroom lessons $\sigma_h$ will be obtained from the expression

$$\sigma_h = \sqrt{\frac{\sum_{i=1}^{n}(\bar{h} - h_s)^2}{n-1}}.$$

*Assessing the proximity of dependent disciplines*

To assimilate the material of certain disciplines di requires knowledge, skills, skills acquired in the study of other disciplines (prerequisites). Moreover, the period between these disciplines should be minimal, since when studying such disciplines, students must resort to knowledge, skills, skills that were obtained in another discipline, that is, it is necessary to restore from memory. Due to the fact that most disciplines from the working curriculum have causal relationships between disciplines, we will define one more criterion. In this case, we will use the methodology for the medium-term forecast of the level of residual knowledge of students:

$$I = I_0 \varepsilon(T), \quad (1)$$

where $I$ is an estimate of the amount of residual knowledge, $I_0$ – assessment of the amount of residual knowledge acquired $T$ years ago by students $\varepsilon(T)$ – function of the form:

$$\varepsilon(T) = \frac{2A}{2A + T}, \quad (2)$$

where A is the constant of forgetting knowledge.

From equation (2) we obtain the share of knowledge remaining after T years from the moment of their study.

We noted above that it is necessary to minimize particular criteria, then to assess the proximity of dependent disciplines, it is necessary to operate with the addition to one, since the value obtained from equation (2) lies in the range from 0 to 1. Proceeding from this, and also taking into account the semesters, and not «years» we get the following equation:

$$\varepsilon(T) = \frac{s}{A+s}, \quad (3)$$

where $s$ is the number of semesters between disciplines.

We have the following expressions for the overall estimate of the amount of residual knowledge:

$$\sigma_z = \sum_{i=1}^{n} \left( \sum\nolimits^{\forall d_j \in B_i^d} \varepsilon\left(\sqrt{(s_i^n - s_i^k - 1)^2}\right)\right), \quad (4)$$

where $s_i^n$ – semester number start of discipline; $s_i^k$ – semester number of the end of the discipline.

*Normalization of partial estimates and construction of a generalizing criterion*

The values of the criterion for the effectiveness of the working curriculum is determined by the vector of its particular criteria $\bar{K}(T_U)$ и the equation can be formalized as follows:

$$\bar{K}(T_U) = \max\{\sigma_h \lambda_h \sigma_z \lambda_z\}, \quad (5)$$

where $\lambda$ – criterion weighting factor.

The above criteria have a certain dimension, which is necessary for the implementation of the minimax approach that these criteria are comparable. To do this, we will normalize the criteria localized in one numerical range. The procedure is expressed in the following form:

$$\bar{K}_i = \frac{K_i - K_i^{\min}}{K_i^{\max} - K_i^{\min}},$$

where $\bar{K}_i$ – normalized value of the i-th criterion; $K_i$ – value of the i-th criterion in calculated units; $K_i^{\min}$ and $K_i^{\max}$ – the minimum and maximum value of a particular criterion of efficiency.

After building a working curriculum and choosing a criterion strategy, it is necessary to optimize the working curriculum. In this regard, the task is to develop a genetic model of such a plan.

**Conclusion**

As a result, the evolutionary genetic algorithm and its projection on the design of interdisciplinary educational programs were considered. The working curriculum is a complex structure and, accordingly, to correctly assess the quality of EP when using this method to solve the problem of developing curricula requires their adaptation and the development of an appropriate multi-criteria approach to assessing the quality of the working curriculum.

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### *Пәнаралық білім беру бағдарламасын жобалау үшін эволюциялық-бағытталған әдістерді қолдану*


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***Аңдатпа.*** *Көп бейінді білім беру бағдарламасын құру көп сатылы процесс болып табылады, өйткені ол студенттің оқу динамикасын көрсетеді және оқу үдерісіне уақытылы түзетулер енгізуге мүмкіндік беруі тиіс.*

*Осыған байланысты мақаланың мақсаты мультидисциплинарлық білім беру бағдарламаларын (ББ) жобалау үшін қажетті әдісті және оны бейімдеуді айқындау болып табылады. Бұл мақалада көпбейінді білім беру бағдарламаларын жобалау кезінде екі немесе одан да көп білім беру бағдарламаларын біріктіру әдісін қолдану қарастырылған. Жалпы алғанда, генетикалық алгоритмнің жұмысы блок-схема түрінде ұсынылған. Эволюциялық-генетикалық алгоритмнің сипаттамасы және пәнаралық білім беру бағдарламаларын жобалауға арналған генетикалық алгоритмнің проекциясы сипатталған. Оқу жұмыс жоспарының сапасын бағалаудың көп өлшемді тәсілі ұсынылған: тәуелді пәндердің жақындығын бағалау, білімді дамытудың біркелкілігін бағалау. Мақалада жеке бағалауды қалыпқа келтіру және жалпылама критерийін құру қарастырылады.*

***Кілт сөздер:*** *ББ жобалау, білім беру бағдарламасы, эволюциялық-генетикалық алгоритм, көпбейінді білім беру бағдарламасы.*

***Применение эволюционно-ориентированных методов для проектирования междисциплинарных образовательных программ***

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***Аннотация.*** *Построение мультидисциплинарной образовательной программы является многошаговым процессом, поскольку она отражает динамику обучения студента и должна позволять своевременно корректировать процесс обучения. В этой связи целью статьи является определение необходимого метода и его адаптации для проектирования мультидисциплинарных образовательных программ (ОП). В данной статье рассмотрено применение метода для слияния двух и более образовательных программ при проектировании мультидисциплинарных образовательных программ. В общем виде работа генетического алгоритма представлена в виде блок-схемы. Описана характеристика эволюционно-генетического алгоритма и проекция генетического алгоритма на проектирование междисциплинарных образовательных программ. Представлен многокритериальный подход оценки качества рабочего учебного плана: оценка близости зависимых дисциплин, оценка равномерности освоения знаний. В статье проведены нормализация частных оценок и построение обобщающего критерия.*

***Ключевые слова:*** *проектирование ОП, образовательная программа, эволюционно-генетический алгоритм, мультидисциплинарная образовательная программа.*

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