The Algorithm For A Single Competition For Admission To Higher Education Programmes

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Abstract:

At the current time admission to universities is carried out on the results of the Unified State Exam as this is a basic way to test graduates' knowledge.
To distribute the vacant places is a difficult task for an admitting committee of an educational institution.

The essence of this task is to enroll students under the conditions of absence of a unified formal mechanism for selecting the best prepared ones to continue their education.

Each contender participates in the competition for a certain set of vacant places. The contender arranges vacancies according to his or her preferences based on priorities.

To rank candidates we input the evaluation function consisting of terms taking into account the results of previous applicant evaluation, assessment of "portfolio" of the applicant to eliminate arising conflicts.

Thus, we have to solve the task of multi-objective general objective function optimization which should satisfy some criteria: select the best prepared candidates to continue their education and take each applicant for no more than one specialty with the highest possible priority and observe restrictions on the number of available vacancies.

According to the results of nationwide competition held on the basis of the results of the Unified State Exam each student is given a certificate attesting the fact that the applicant has earned the right to study at the expense of the federal budget and the applicant himself may choose an educational institution if the points he or she scored are enough for it.

This approach allows us to determine which educational institution has more prestige among the entrants.

Thus, the article suggests an algorithm of the nationwide competition in the system of higher education which allows choosing the best prepared candidates and ranking the educational organization.

Main Text:

In 2009 in Russia transition to the unified state exam (USE) as to the main way of control of knowledge for graduates of schools and to the main selection criterion came to the end at reception in higher educational institutions. Pupils of graduation classes are obliged to choose the list of the handed-over subjects of Unified State Exam in certain terms. This information gathers educational bodies and accumulates in a uniform information database.

Since 2012 the Ministry of Education and Science of the Russian Federation made the decision on allocation of the budgetary places to higher education institutions not on the integrated groups of the directions of directions of training and specialties (IGDS), but on the certain directions of training of bachelors and masters and specialties according to federal state educational standards. Besides, since 2012 the Ministry of Education and Science of the Russian Federation passed to the scheme of "per capita" financing of higher education institutions. That is if the higher education institution receives N budgetary places in some direction of preparation (specialty), this higher education institution is annually stated subsidy at a rate of N*K of rubles, where K is the standard of costs of unit of the state service for reception is given for the first course in the current year which differs for different specialties, form of education and education level.

For strengthening of measures for control over observance of normative documents in the field of enrollment of students, for ensuring the maximum openness of procedures of reception in relation to entrants, since 2012 the federal information system of ensuring Unified State Exam and reception to specialised secondary educational establishment and higher education institutions (FIS) is put into operation. In FIS all data on entrants of each Russian higher education institution with the indication of the specialties and the directions chosen by them for receipt, the privileges gained on Unified State Exam and entrance tests points, etc. are brought.

Thus, now the Ministry of Education and Science of the Russian Federation before transfer in higher education institutions on 1 course possesses the following data [1]:

1) the full list of all future entrants with the indication of their personal information which confirmed desire to pass the Unified State Examination in the current year;

2) information on the subjects of Unified State Examination chosen by each of entrants;

3) information on quantity of the budgetary places on each direction of preparation or specialty;

4) results of Unified State Examination of each entrant (after the end of procedure of carrying out Unified State Examination for all Russia).

We will assume that the following two conditions will be satisfied: first, at a stage of delivery of demands for Unified State Examination all school students will also bring in a federal database the list of specialties and the directions of preparation they are going to (with the indication of form of education), and information about privileges and advantages, secondly, in all higher education institutions of Russia identical entrance tests will be declared on the identical directions of preparation and specialty.

If these two assumptions are realized, it will be possible to realize new algorithm of the All-Russian competition at enrollment of students of Russia, based on [2, 3, 4, 5, 6].

The essence of competition consists in distributing a great number of applicants (entrants, school students) ($P = \bigcup p_i$ ($i = \overline{1, K}$) on a set of the available vacancies (the places financed from means of the federal budget of Russia) $V = \bigcup V_l$ ($l = \overline{1, N}$). Each of applicants participates in competition on some set of vacancies (places within one specialty or the direction of preparation) from a set V ($V_i^P \subseteq V$). The applicant orders vacancies from V_i^P according to the preferences, i.e. every $V_l \subset V$ puts in compliance its priority – the whole non-negative number $s(p_i, V_l)$, and $s(p_i, V_l) = \infty$ for all $V_l \not\subset V_i^P$ and $1 \le s(p_i, V_l) \le \left| V_i^P \right|$, $s(p_i, V_{l1}) \ne s(p_i, V_{l2})$ for any $l1 \ne l2$, $l1, l2 = \overline{1, \left| V_i^P \right|}$. To each vacancy V_l there corresponds the formalized representation of group of requirements $U_l = \bigcup u_{l,k}$,

where $k = \overline{1, |U_l|}$ which performance is necessary for receiving the right for the applicant to occupy one of vacancies V_l. Examples of such requirements are overcomings of threshold value on each of the subjects which are handed over by the applicant. Each applicant corresponds to one of the categories determined by the legislation of Russia $CP_j \in CP$, $j = \overline{1, |CP|}$. Progress of the applicant before reception is characterized by a vector of estimates by dimension of *N1* $O_i = (o_{i1}, o_{i2}, ..., o_{iN1})$, $i = \overline{1, K}$ (in fact these are estimates of the entrant in the document on education which is available for it).

To range applicants, it is necessary to count value of the modified estimated function for each competitive position of the applicant:

$$z(p_i, V_l) = \left(\sum_{k=1}^{|U_l|} r(p_i, u_{l,k}) \cdot q(u_{l,k}) + SB(p_i, V_l) S_{max} + NET(p_i) F_{max} + W(p_i, V_l) \right) \cdot \prod_{k=1}^{|U_l|} h(p_i, u_{l,k}) \quad (1)$$

where

- $r(p_i, u_{l,k})$ – a quantitative assessment of performance of the requirement $u_{j,k}$ by the applicant p_i from a set U_l, i.e. results of tests (Unified State Examination);

- $q(u_{l,k})$ - the weight coefficient of an indicator k from a set of requirements U_j determined by the legislation of Russia in the field of education;

- $0 \leq SB(p_i, V_l) \leq 1$ - function of an assessment of results of the previous certification of the applicant;

- S_{max} - maximum possible score appointed for results of the previous certification of the applicant (according to offers of the Ministry of Education and Science of the Russian Federation it is planned to establish since 2015 it to equal 10 points);

- $0 \leq NET(p_i) \leq 1$ - assessment of "portfolio" of the applicant, i.e. individual achievements and abilities of the applicant to scientific, creative, sports and other activity;

- F_{max} - maximum possible score appointed for the applicant's "portfolio" (according to offers of the Ministry of Education and Science of the Russian Federation it is planned to establish since 2015 it to equal 10 points);

- $W(p_i, V_l) >> \sum_{k=1}^{|U_l|} r(p_i, u_{l,k}) \cdot q(u_{l,k}) + SB(p_i, V_l) S_{max} + NET(p_i) F_{max}$ - the function defining the order of ranging of various categories of applicants approved within the legislation of Russia. Value $W(p_i, V_l) = W(CP_j)$ if the applicant corresponds to category CP_{j1}. If applicants of category CP_{j1} apply

for prime transfer in comparison with applicants of category CP_{j2}, then $W(CP_{j1}) >> W(CP_{j2})$;

- $h(p_i, u_{l,k})$ - performance sign ($h(p_i, u_{l,k}) = 1$) or non-performance ($h(p_i, u_{l,k}) = 0$) the applicant p_i of condition k from a set U_l.

Function of an assessment of results of the previous certification of the applicant which area of values is in range [0; 1], is defined as:

$$SB(p_i, V_l) = \frac{\|O_i^l - O_{\min}\|}{\|O_{\max} - O_{\min}\|} = \sqrt{\sum_{k=1}^{\dim O_{\max}} (o_{i,k}^l - o_{\min k})^2 \bigg/ \sum_{k=1}^{\dim O_{\max}} (o_{\max k} - o_{\min k})^2} \quad (2)$$

where

- O_i^l - vector with estimates by results of the previous certification of the applicant for the subjects and disciplines corresponding to vacancy V_l;

- $O_{\min}$ - vector of threshold values of the same dimension ($\dim O_{\min} = \dim O_i^l$), corresponding to the minimum estimates confirming development by the applicant of the program for the corresponding disciplines;

- $O_{\max}$ - vector of limit values ($\dim O_{\max} = \dim O_i^l$), characterizing the "ideal" applicant and corresponding to the maximum possible estimates on each discipline.

Terms $SB(p_i, V_l)$ and $NET(p_i)$ are also entered for elimination of collisions at a choice of applicants. The essence of the arising collisions is reduced to the fact that the great number of applicants $P_l^C \subset P$, $|V_l^C| < |P_l^C|$, with identical value of estimated function $z(P_l^C, V_l^C)$ applies for some subset of vacancies $V_l^C \subset V_l$.

The assessment of results on a formula (2) is to a lesser extent subject to influence of "big deviations" and possesses higher differentiating property allowing 10% more than collisions in comparison with use of an arithmetic average of value.

Result of decision-making on reception on the second and the subsequent courses is finding of a matrix of transfers D by dimension K on N each element of which $d_{il} = d(p_i, V_l)$ is equal to unit if as a result of competitive selection the applicant p_i is recommended for enrollment (transfer) to vacancy of a subset V_l, and is equal to zero otherwise. For finding of a matrix of D it is required to solve a problem of multicriteria optimization of the general criterion function corresponding to reception of the applicants who are most prepared for the continuation of training providing the set change of financing of higher education institution at transfer of each applicant no more than on one specialty with the greatest possible priority and at observance of the restrictions on quantity which are available vacancies:

$$\max_{x \in X} F_C(x), F_p^i(x); i = 1,2,...,K \ , \ x = (d(p_1,V_1), d(p_1,V_2),...,d(p_K,V_N)) \, ,$$

$$X = \left\{ x \,\middle|\, d(p_i,V_l) = \{0;1\}, \forall l \left(\sum_i d(p_i,V_l) \le |V_l| \right), \forall i \left(\sum_l d(p_i,V_l) \le 1 \right); i = 1,2,...,K; l = 1,2,...,N \right\}, \quad (3)$$

Where

$$F_C(x) = \sum_i \sum_l d(p_i,V_l) \cdot z(p_i,V_l) \quad (4)$$

$$F_p^i(x) = \sum_l d(p_i,V_l) / s(p_i,V_l) . \quad (5)$$

$F_C(x)$ -   the criterion function corresponding to reception of the applicants who are most prepared for development of a further educational program (having the greatest score by results of Unified State Examination).

$F_p^i(x)$ -   criterion function of the applicant p_i who is interested in occupation of vacancy with the greatest priority.

Thus it is necessary to provide performance of a condition: for each applicant p_i distributed on vacancy $V_l^{/}$ there is no vacancy $V_l^{//}$, such as $z(p_i,V_l^{//}) \ge \min_{i1}(z(p_{i1},V_l^{//}) \cdot d(p_{i1},V_l^{//}))$ and $s(p_i,V_l^{//}) < s(p_i,V_l^{/})$ for $i1 : s(p_{i1},V_l^{//}) \ne \infty$.

For finding of suboptimum value x (and, respectively, a matrix of D) on condition of a choice as the main criterion $F_C(x)$ the following algorithm is created:

1.   For all competitive positions $z(p_i,V_l)$ is calculated.

2.   For each set of vacancies the rating list of the applicants ordered on decrease of values of estimated function is under construction, the matrix of transfers D is nullified, all competitive positions are noted as raw.

3.   From a rating list the first set of identical vacancies gets out V_{max}.

4.   The raw competitive position and the applicant p_{max} corresponding to it with estimated function $z_{max} = \max(z(p_i,V_{max}))$ gets out. If all positions are processed, we mark V_{max} as processed and pass to point 6.

5.   If $\sum_i d(p_i,V_{max}) < |V_{max}|$, i.e. there are free vacancies, and there are no collisions, to distribute on one of vacancies p_{max}, i.e. to establish $d(p_{max},V_{max}) = 1$. For all V_l, such as $s(p_{max},V_l) > s(p_{max},V_{max})$ establish

$d(p_{\max}, V_l) = 0$, and to mark all competitive positions $z(p_{\max}, V_l)$ as processed with the note that $p_{\max}$ is distributed on $V_{\max}$. Also to designate the current competitive position as processed. If there were changes of a matrix of transfers, except in a position $d(p_{\max}, V_{\max})$, pass to point 3, differently – pass to point 4.

6. From a rating list the following raw set of identical vacancies $V_{\max}$, transition to point 4 gets out. If V is processed and there was no change of matrix D, the end of algorithm, differently transition to point 3.

The optimality of the decisions received as a result of work of this algorithm for small K and N values, is confirmed with coincidence of results of its work to the results received by method of full search that allows to draw a conclusion on a suboptimality of the received decisions for great values of K and N. Thus it is experimentally shown that the assessment of operating time of the offered algorithm makes $O\left(\sqrt{N \cdot K} \cdot \log N \cdot \log K\right) \sim O(n \cdot \log n)$ while the assessment of operating time of the algorithm realizing full search makes $O\left(\prod_{i=1}^{K} \left|V_i^P\right|\right) \sim O\left(c^n\right)$.

By results of such All-Russian competition each entrant can be granted the certificate confirming the fact of that the entrant deserved the right to be trained at the expense of means of the federal budget. In that case instead of carrying out open public competition from higher education institutions the budgetary places and, respectively, financing to educational institutions it can be distinguished on the basis of data on the entrants who presented originals of the above certificates and documents on education to educational institution.

Introduction of such practice will allow to resolve finally an issue of what higher education institution is preferable more to entrants who will raise a rating of higher education institution, presenting to it the certificates (such as [7]).

Introduction of the specified approach will allow to reduce considerably a flow of entrants in higher education institutions during reception campaigns, to simplify work of selection committees. Now from the lump of entrants 50% of total of the natural persons who submitted the application for reception go to the university on average. Respectively, processing of documents of the remained half of entrants is unnecessary work which can be avoided in the light of the offered method of the organization of reception.

Also offered approach guarantees that the entrant with high points of Unified State Examination doesn't remain without deserved budgetary place. Now situations when the entrant is compelled to study on a paid basis are frequent only because he or she didn't submit the application to one of universities where his or her point was through passage.

It is natural that there is a number of higher education institutions which won't be limited at reception only to results of Unified State Examination and will carry out additional entrance tests of a profile, creative or professional orientation. Such right can be granted to a certain list of higher education institutions (as it is organized now),

having allowed to hold additional competition among the entrants having certificates by results of the entrance tests conducted by educational institution independently.

We will note that the entrant can grant the right to be tranferred from that university to which he entered on the basis of the certificate, to any other if he or she successfully hands over sessions, but won't be satisfied with quality of educational or other services of initially chosen educational institution.

Thus, in work the algorithm of carrying out the All-Russian competition in the directions of preparation and specialties of the higher education at enrollment of students of Russia allowing to provide training in the higher education institutions which are most prepared (from the point of view of the level of results of Unified State Examination) entrants, to define an objective rating of popularity of the Russian educational institutions, to provide high mobility of students is offered.

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