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A. Glybovets

AGENT-BASED MODELING

Article is about key methodology in agent-based modeling and main agent-based products.

Keywords: agents modeling, agents, agent-based model, environment for development of agents models.

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RESEARCHING SEMISTRUCTURED PROBLEMS OF MULTICRITERIA OPTIMIZATION USING THE SOFTWARE SYSTEM

Develop the optimal decision support system for solving semistructured problems of multicriteria optimization, which can be used by individual or collegial body who take responsible decisions. Currently existing software tools, which solve this class problems are limited only by finding the best alternative, whereas the proposed system also (in addition to solving this problem) allows to develop instructions ("guidelines for actions") for any of losing alternatives so that the observance of them will guarantee the winning for this alternative.

Keywords: semistructured problems, multicriteria optimization, analytic hierarchy process, criteria, alternatives.

Among multicriteria problems connected with decision support [1–4], which very often occur in practice, the problems of alternatives choosing stay actual [5–7]. Mathematically, such problems are described by a set of alternatives and all of them are given the values of certain parameters (criteria).

The solution of this problem is an alternative which has the best (as a whole) criteria values, which generally are distinct in significance.

As a rule, people always try to make the best choice. But people's opportunities to analyze information in a deep way are not unlimited. Nowadays, it is felt especially, because humanity gradually enters the era of the informational society, when, on the one hand, we receive more and more knowledge about the world around us, and on the other hand, we don't have enough time to reconsider this information, because we are often forced to make decisions under time constraints. What is the solution? To our mind, the situation could be improved by "smart" computer programs with an easy interface, which would play the role of assistants. Obviously, over time these kinds of software systems would become more and more demanded.

Review of decision support systems (including semistructured problems solving systems) can be found in works [8, 9]. Currently existing software tools, which solve this class problems are limited only by finding the best alternative, whereas the proposed system also (in addition to solving this problem) allows to develop instructions ("guidelines for actions") for any of losing alternatives so that the observance of them will guarantee the winning for this alternative. This is the main result of the work.

Functionally, the software system consists of two main parts: the first finds the best alternative by the Analytic Hierarchy Process (hereinafter, AHP), the second generates for any other alternative "guidelines for actions" (by developed algorithm).

The main scientific result of the work is the algorithm for solving those multicriteria optimization problems, in which alternatives can change (improve) their states. We developed new algorithm, which allows to receive recommendations for any of losing alternatives so that the observance of them will guarantee the winning for this alternative.

The practical significance of the work is reflected in construction of complete software product, which can be used by people who make responsible decisions (in various areas of human activity).

The software system is developed in an integrated environment Delphi 7 in accordance to the concept of Graphical User Interface (GUI), so the proposed system has user-friendly interface intended to non-professional users.

1. Analytic Hierarchy Process

The AHP [5] was developed by American mathematician T. Saaty in 1980. Nowadays AHP is one of the best known methods for solving semistructured problems of multicriteria optimization, connected with making important decisions. Its main stages are:

1. Structuring the problem of choosing the best alternative in the form of hierarchy. In a minimal form such kind of hierarchy should consist of three levels: the goal of problem (the first level), through criteria which are taken into account when solving the problem (the second level) to alternatives, from which we should choose the best (the third level). This AHP stage is called "The principle of identity and decomposition".
2. Pairwise comparisons between elements of the same hierarchy level from the perspective of their influence on the hierarchy element located the level above. The name of this stage is "The principle of discrimination and comparative judgments".
3. Receiving local priorities of the hierarchy elements located on the same level; they characterize the relative influence of the elements located on the same level on the element located at the higher level.
4. Receiving global priorities for all alternatives; algorithm takes into account local priorities calculated previously. In fact, this is the final stage of solving the problem, i.e. the alternative with the highest global priority is the best. Stages 3 and 4 together called "The principle of synthesis".

Let's consider the essence of each step in more detail.

1.1. Identity and decomposition principle

The process of problem structuring executing by people who make important decisions may need carrying out additional analysis to be sure that criteria and alternatives cover all existing preferences of discussion participants and constructed hierarchy represents them adequately. It is not necessary for all participants to come to an absolute agreement in the planning process, because further the process participants express their vision of "importance" (or weight) of the hierarchy element during the pairwise comparisons realization. And if somebody of discussion participants considers that the element is not essential, then he would estimate it in an appropriate way. It means that AHP can be characterized as "democratic" method.

1.2. Discrimination and comparative judgments principle

After constructing hierarchy, the following question arises: "How to establish criteria priorities and evaluate all alternatives according to these criteria to choose the best of them?"

1.2.1. Pairwise comparisons

The hierarchy elements of one level are compared pairwise with regard to their influences on the hierarchy element located the higher level. Comparing the elements with each other, we have a square matrix of the following form:

$$\begin{pmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{pmatrix}, \text{ where } a_{ij} = \frac{1}{a_{ji}},$$

i.e. the reverse compatibility property is valid for the matrix (the indices i and j denote the row and column respectively).

Let $A_1, A_2, \supset, A_n$ be the set of n elements and $w_1, w_2, \supset, w_n$ be values of their importance; their pairwise comparisons are shown in Table 1.

Table №1. **Pairwise comparisons of the weight of each element**

	A_1	A_2	...	A_n
A_1	1	w_1/w_2	...	w_1/w_n
A_2	w_2/w_1	1	...	w_2/w_n
...	...	...	1	...
A_n	w_n/w_1	w_n/w_2	...	1

Similar matrices should be built on other hierarchy levels. For example, if the hierarchy consists of three levels (level of the goal, level of criteria and level of alternatives), where n is an amount of criteria, m is an amount of alternatives, then we have $(n+1)$ square matrix of pairwise comparisons: one $n \times n$ matrix and n $m \times m$ matrices.

1.2.2. The recommended scale for pairwise comparisons

To be able to describe subjective pairwise comparisons numerically, we need the scale where these comparisons will be implemented. The AHP uses the scale, which is given in Table 2. It is proved, that this scale is correct and this scale is enough to solve a lot various practical problems of multicriteria optimization.

Table №2. **Recommended scale of comparisons**

Index of relative importance	Definition
1	Equal weight
3	Slight advantage
5	Noticeable advantage
7	Strong advantage
9	Absolute advantage
2, 4, 6, 8	Intermediate values
Above digits reciprocals	Element yields similarly

When using this scale, we need to follow some rules, for example:

1. to compare the weight of left element with the weight of element located above for each matrix cell: if first weight is more than the second, we should put an integer number from the scale, otherwise – the reciprocal one;
2. diagonal matrix cells consists of "1";
3. symmetric matrix cells consists of reciprocals; therefore it is enough to implement $n(n-1)/2$ comparisons to fill the $n \times n$ matrix;
4. during pairwise comparing of alternatives by the criterion the following question arises: "Which alternative is more preferable?" during pairwise comparing of criteria with respect to the goal the following question arises: "Which criterion is more significant?"

1.3. The priority synthesis

1.3.1. The synthesis: local priorities

From the group of pairwise comparisons matrices consisting of one-level hierarchy elements the local priorities are calculated; the local priorities show the relative influence of these elements on the hierarchy element, located the higher level.

In practice, to calculate the local priorities approximately it is often used the geometrical average, when you need to multiply the elements of each matrix row and calculate the root of n^{th} power from this product (where n is an amount of row elements). Furthermore, this column of numbers must be normalized. For this, each number should be divided on the sum of all these numbers. For example, for Table 1 the components of local priorities vector L_i could be received this way:

$$L_i = \frac{\sqrt[n]{\frac{w_i}{w_1} \cdot \frac{w_i}{w_2} \cdot \ldots \cdot \frac{w_i}{w_n}}}{\sum_{j=1}^{n} \sqrt[n]{\frac{w_j}{w_1} \cdot \frac{w_j}{w_2} \cdot \ldots \cdot \frac{w_j}{w_n}}}, \quad i = \overline{1,n}.$$

Typically, these calculations are started from the second hierarchy level (criteria level); calculations are gradually continued for all subsequent levels; they are finished by formation of local priorities for the lowest level (alternatives level).

1.3.2. The consistency of local priorities

Very important parameter for each matrix is the Value of Consistency (hereinafter VC), which gives an information about deviation level for both transitive and numerical (cardinal $a_{ij} \cdot a_{jk} = a_{ik}$) consistency. In general, we have inconsistent matrices.

That's why solving a practical problem we need to have a criterion of level consistency estimation of matrices. Such parameter is the VC.

It is quite hard to find an ideal consistency in practice. But it is not necessary. It is enough to control finding the VC parameter in certain boundaries; when the VC value is not in these boundaries, then decision maker should implement the matrix data correction.

The algorithm of approximate calculation of the VC is:

1. calculate the sum of each matrix column;

2. multiply the sum of the first column $\sum_{j=1}^{n} a_{1j}$ by the first component of priority vector L_1; multiply the sum of the second column $\sum_{j=1}^{n} a_{2j}$ by the second component of priority vector L_2, etc;

3. calculate the sum of these numbers (»$_{\max}$):

$$\lambda_{max} = \sum_{i=1}^{n}\left(L_i \cdot \sum_{j=1}^{n} a_{ij} \right);$$

4. calculate the Consistency Index (IC): $IC = (\lambda_{max} - n)/(n-1)$, where n is the matrix dimension; (for anti-symmetric matrix $\lambda_{max} \geq n$);

5. calculate VC: $VC = IC / VRC$, where VRC is the Random of Value Consistency, which could be received in case of random choice of comparative judgments from the scale $\left\{\frac{1}{9},\frac{1}{8},\frac{1}{7},\ldots,\frac{1}{2},1,2,\ldots,9\right\}$ for anti-symmetric matrices. The values of VRC for different dimension matrices are:

Matrix dimension	1	2	3	4	5	6	7	8	9	10
VRC	0	0	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49

The calculated VC should not exceed 20%. To improve consistency we recommend to search additional information and to correct data.

1.3.3. The synthesis: global priorities

The final stage of the AHP consists of local priorities synthesis (linear convolution) in the hierarchy. As a result, priorities of alternatives relatively the goal are calculated (global priorities). The alternative, which has the highest value of global priority, is the best. The algorithm of global priorities calculating is shown below:

The priorities are synthesized starting from the second and finishing by the lowest hierarchy level.

The local priorities are multiplied by the appropriate criterion priority located the higher level and summarized by each element in accordance to the criteria, on which this element influences.

The process continues up to the lowest level. For example, for the hierarchy which consists of three levels (goal, criteria, alternatives) the global priorities could be calculated using the following formula:

$$G_k = \sum_{i=1}^{n}(L_i \cdot L_{ki}),\ \ k = \overline{1,m},$$

where G_k is the global priority of the k^{th} alternative; L_i s the local priority of the i^{th} riterion with respect to the goal; L_{ki} s the local priority of the k^{th} lternative with respect to the i^{th} riterion. The solutions of the problem are calculated values of global priorities, i.e. the alternative which has the highest G_k alue is the best.

2. Algorithm of generating recommendations for losing alternatives

The software system develops recommendations how to make desirable alternative of the best for problems of multicriteria optimization in which alternatives can change the state. Let n be the number of criteria, m be the number of alternatives, $A = \{A_1, A_2, \ldots, A_m\}$ be the set of alternatives, A_{best} be the best current alternative, $A^* \in A \setminus A_{best}$ be the alternative for which recommendations are developed.

Search of recommendations for A^* starts from the search of a certain average alternative (it can vary with respect to criteria), concerning which changes of the state of A^* are analyzed. The choice of such average alternative is carried out on the basis of local priorities at the level of criteria (that is the alternative which is not neither the best, nor the worst is selected, and its local priority by this criterion is approximately in the middle). Such approach allows us to analyze all possible state changes of A^* unlike a case when any other alternative is chosen for comparing. It should be noted that for comparing it is not reasonable to choose A_{best} because it can lead to unfairly excessive recommendations for A^* whereas comparing with average alternative will allow to receive such recommendations which will demand the minimal changes of A^*. For carrying out the full analysis it is reasonable to have opportunity to do rather minor changes of the current state of A^* which in the meantime could lead to the goal (i.e. the alternative becomes the best). It is provided by the average alternative.

A^* becomes the best if its global priority reaches maximum. For this purpose it is necessary to improve values of local priorities of A^* by certain criteria, and it requires creation of new local priorities for the new (changed) status of A^*.

For computation of local priorities for new states of A^* it is necessary to create matrices of pairwise comparisons of all possible improvements of A^* with respect to the average alternative by all criteria. Let us consider this approach through the example of k^{th} criterion. Let C_k be the average alternative by the k^{th} criterion. Compare the alternatives A^* and C_k using all possible ways for every value from the scale $\left\{\frac{1}{9},\frac{1}{8},\frac{1}{7},\ldots,\frac{1}{2},1,2,\ldots,9\right\}$ and fill out the matrix of pairwise comparisons of new state of A^* (see the cells in braces in Table 3); in this case the values of the pairwise comparisons A^* with other alternatives are updated (see the cells with $w_{A^*_{new}}$ in Table 3, where $w_{A^*_{new}}$ is a new weight of A^* after improvement).

Table №3. **Matrix of pairwise comparisons of alternatives' importance (after changing of alternative A*)**

	A_1	A^*	C_k	…	A_n
A_1	1	$w_i/w_{A^*_{new}}$		…	w_1/w_m
A^*	$w_{A^*_{new}}/w_1$	1	{9, …,1/9}	…	$w_{A^*_{new}}/w_1$
C_k		{9, …,1/9}	1		
…	…			1	…
A_m	w_m/w_1	$w_m/w_{A^*_{new}}$		…	1

Then, compute the difference between the local priorities of a new state of A^* and the best alternative A_{best} for the given matrix of pairwise comparisons. Let $L_{i,k}(A)$, $i\in\left\{\frac{1}{9},\frac{1}{8},\frac{1}{7},\ldots,\frac{1}{2},1,2,\ldots,9\right\}$ be new local priority for the alternative A by k^{th} criterion; $L_k(A)$ be old (initial) local priority by criterion k; w_k be weight of k^{th} criterion. Then, the contribution to the global priority by k^{th} criterion given that A^* become better with respect to C_k over the scale $i\in\left\{\frac{1}{9},\frac{1}{8},\frac{1}{7},\ldots,\frac{1}{2},1,2,\ldots,9\right\}$ is equal to

$$\Delta_{i,k}=\left(\left(L_{i,k}(A^*)-L_{i,k}(A_{best})\right)-\left(L_k(A^*)-L_k(A_{best})\right)\right)*\mathrm{w}_k.$$

Let us write $\Delta_{i,k}$ to Table 4. The problem of generating recommendations for the alternative A^* is reduced to the following optimization problem:

$$h(\Delta)=\sum_{k=1}^{n}\Delta_{i_k,k}-\left(G(A_{best})-G(A^*)\right)\to\min, \quad (1)$$

where $h(\Delta)>0, i_k\in\left\{\frac{1}{9},\frac{1}{8},\frac{1}{7},\ldots,\frac{1}{2},1,2,\ldots,9\right\}$.

Table №4. **Direction of improvement of alternative's A^* weight relatively middle (by each criterion) alternatives**

Scale	Criterion K_1	Criterion K_2	Criterion K_3	…	Criterion K_{n-1}	Criterion K_n
9	$\Delta_{9,1}$	$\Delta_{9,2}$	$\Delta_{9,3}$		$\Delta_{9,n-1}$	$\Delta_{9,n}$
8		↑		↑		
…	↑	0 ↑	↑	0 ↑		↑
…	0 ↑		0 ↑		↑	0 ↑
$\frac{1}{8}$					0 ↑	
$\frac{1}{9}$	$\Delta_{\frac{1}{9},1}$	$\Delta_{\frac{1}{9},2}$	$\Delta_{\frac{1}{9},3}$		$\Delta_{\frac{1}{9},n-1}$	$\Delta_{\frac{1}{9},n}$

Thus, for every criteria ($k=\overline{1,n}$) it is necessary to find out such indexes i_k which minimize $h(\Delta)$ (resulting factor of efforts for A^*). Let us illustrate this by Table 4, which demonstrates the amount of possible approaching to the best alternative according to global priority.

Here, zeros are the cells corresponding to initial (old) state A^* with respect to the average alternative by K_i^{th} criterion; these values do not give any improvement for new global priority and thus they are posed equal to 0, i.e. $\Delta_{\mathrm{k}_{start},k}=0$; k_{start} is an initial value of pairwise comparison of A^* with the average alternative by the k^{th} criterion, i.e. $\mathrm{k}_{start}\in\left\{\frac{1}{9},\frac{1}{8},\frac{1}{7},\ldots,\frac{1}{2},1,2,\ldots,9\right\}$. The development of recommendations for every criterion (every column) is made along the arrows.

Beyond the resulting factor of efforts (1), it is possible to compute the number of steps, which need to be executed that A^* became the best (for every recommendation). Here, the step is a transition to the next position in the scale $\left\{\frac{1}{9},\frac{1}{8},\frac{1}{7},\ldots,\frac{1}{2},1,2,\ldots,9\right\}$ (for example, the step is the changing of the alternative state from $\frac{1}{8}$ to $\frac{1}{7}$ or from 2 to 3). Denote by num a function which maps one-to-one the elements of the scale AHP to the set of natural numbers from 1 to 17, i.e. $num:\left\{\frac{1}{9},\frac{1}{8},\frac{1}{7},\ldots,\frac{1}{2},1,2,\ldots,9\right\}\to\{1,\ldots,17\}$. Then, the resulting number of steps needed to achieve the goal equals

$$\sum_{k=1}^{n}\left(num(i_k)-num(k_{start})\right),\ h(\Delta)>0, \qquad (2)$$
$$i_k\in\left\{\frac{1}{9},\frac{1}{8},\frac{1}{7},\ldots,\frac{1}{2},1,2,\ldots,9\right\}.$$

However, the efforts weighed by criterion are more useful and informative:

$$\sum_{k=1}^{n}\left(w_k*\left(num(i_k)-num(k_{start})\right)\right),\ h(\Delta)>0. \quad (3)$$

This formula takes into account the weight of every criterion for the goal achievement.

Let us demonstrate the simplified description of the algorithm:

0) k=1; $j_1 = j_{1(start)}$, $sum = 0$.

1) If $k = 0$, Stop.

2) If $j_k \geq 9$, go to Step 3, else

$sum = sum - \Delta_{j_k,k}$, $j_k = j_k + 1$, $sum = sum + \Delta_{j_k,k}$,

if $sum - \left(G\left(A_{best}\right) - G\left(A^*\right)\right) > 0$ commit j^{th} recommendation and go to Step 3,

else if $k < n$ then $k = k+1, j_k = j_{k(start)}$, go to Step 1.

3) $sum = sum - \Delta_{j_k,k}$, $k = k-1$, go to Step 1.

3. The description of software system

3.1. Testing of the program: choosing the best house to buy

Problem formulation. From three houses (alternatives) it is necessary to choose the best, taking into account eight factors (criteria). This problem was proposed and solved by T.Saaty [7], the author of the AHP. We solve this problem to test the program and to compare our results with Saaty's results [7].

For the correctness of this test all input data were taken from [7]. Representing the problem as a hierarchy is shown in Fig.1; pairwise comparisons of criteria and alternatives are shown in Fig.2 and Fig.3 accordingly; results of calculations are shown in Fig.4. The global priorities for each house differ from Saaty's results not more than by 0.01.

It proves that results which were received by software system are highly accurate and authentic.

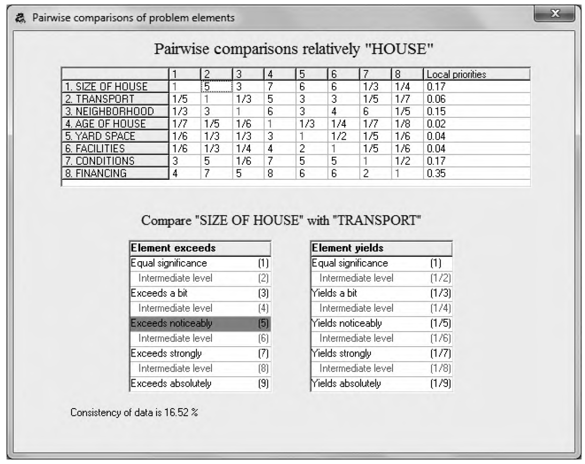

Fig. 2. Pairwise comparisons of criteria

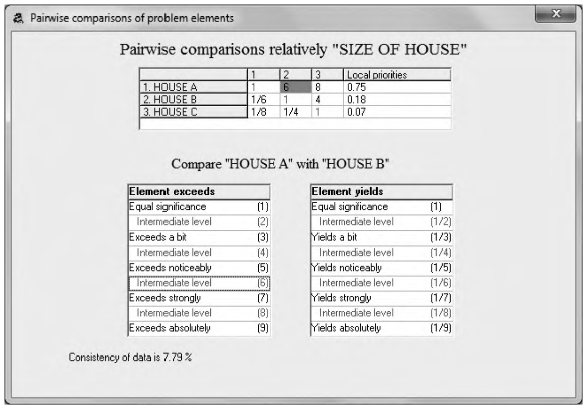

Fig. 3. Pairwise comparisons of alternatives

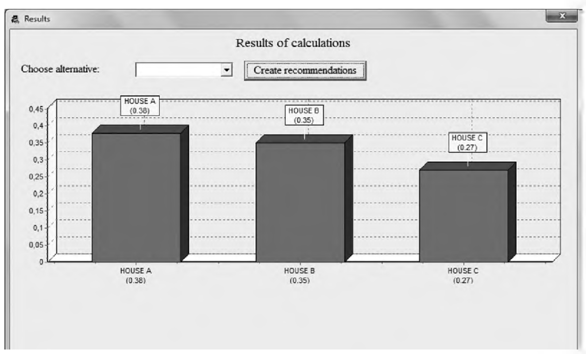

Fig. 4. Results of calculations

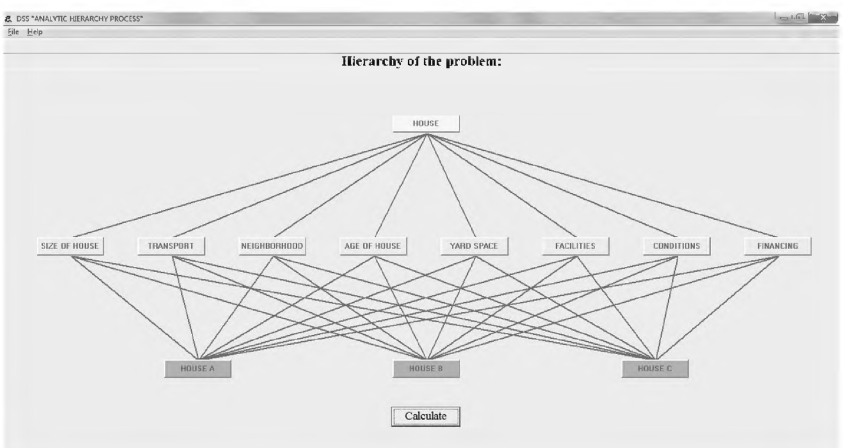

Fig. 1. Representing the problem as a hierarchy

3.2. Problem of the best footballer choosing and formulating recommendations for losing alternatives

Problem formulation. Let's imagine, that there are several footballers who are nominated for the FIFA (International Federation of Association Football) Ballon d'Or award. It is necessary to make the optimal choice, taking into account several criteria.

Solving the problem using the software system. After program launching, solving the new problem starts with the command "Create new project…" located in File menu. The command will display the dialog box (Fig. 5), where it is necessary to enter short name of the problem, amount of criteria and alternatives; in the Comment field a more detailed description of the problem could be input. Let's assume that decision maker choose one of four alternatives: {"C.Ronaldo", "Messi", "Ibrahimović", "Iniesta"}. Also let's assume that decision maker wants to take into account seven criteria: {"Dribbling", "Athleticism", "Pass", "Kick", "Speed", "Playmaker", "Endurance"}.

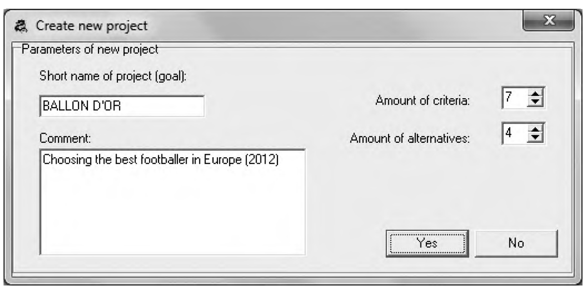

Fig. 5. Creation of a new project

Let us emphasize that all calculations made by software system are the result of subjective point of decision maker's view. That is why the results of calculations for the same problem by various decision makers could differ.

After pressing the "Yes" button the hierarchic view of the problem with the corresponding number of criteria and alternatives appears (Fig. 6).

In this window, using the context menu user may add or delete a criterion or alternative of an element of hierarchy, edit its name, make comments, and load photos. User may add up to 9 criteria and up to 9 alternatives. There are 3 levels of hierarchy (the first level is a goal, the second level are criteria, the third level are alternatives). For the most practical problems of multicriteria optimization these restrictions are insignificance. The dialog box for input data for the alternative is shown on Fig. 7.

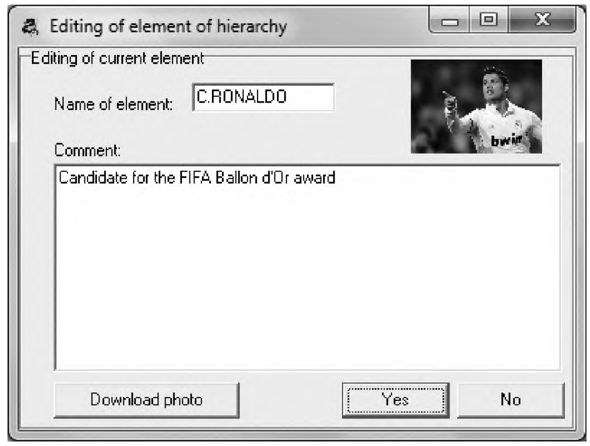

Fig. 7. Editing of element of hierarchy

Pressing left mouse button at the highest element of hierarchy opens the dialog box for input of the matrix of pairwise comparisons of criteria. We fill out it using the linguistic scale located in the bottom. The right column of matrix contains computed local priorities, and below we can see the value of matrix consistency. If this value exceeds , the system makes a warning as a red string (Fig. 8).

Pressing left mouse button at some criterion opens an analogous dialog box for input pairwise comparisons of alternatives (Fig. 9).

After data input the user can press the "Calculate" button. The result is shown in Fig. 10.

"Messi" won. Let us develop recommendations for a victory, for example, "Iniesta". Let us choose

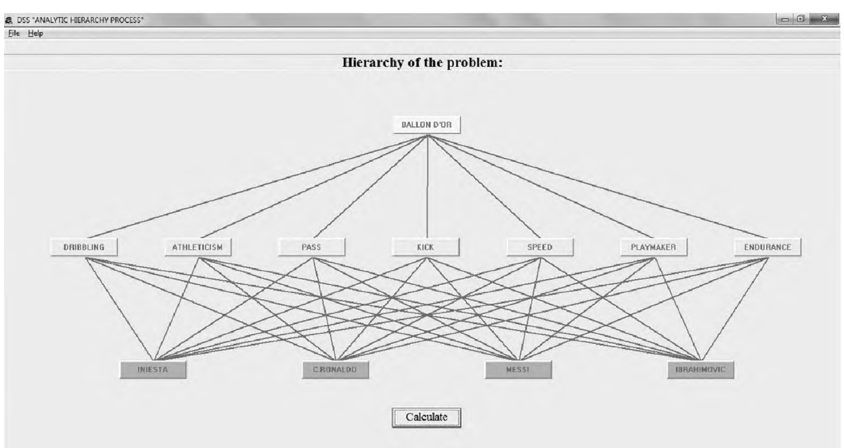

Fig. 6. Representing the problem as a hierarchy

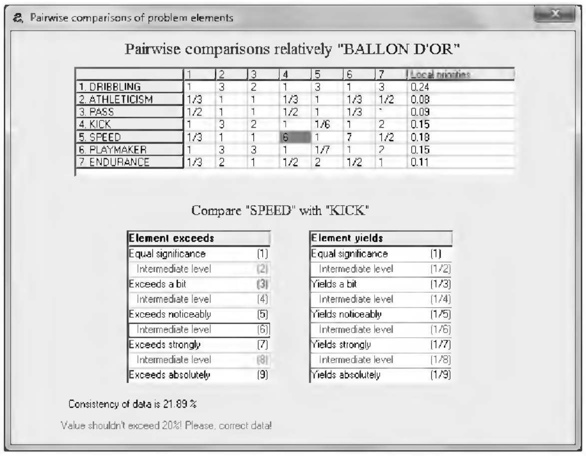

Fig. 8. Pairwise comparisons of criteria

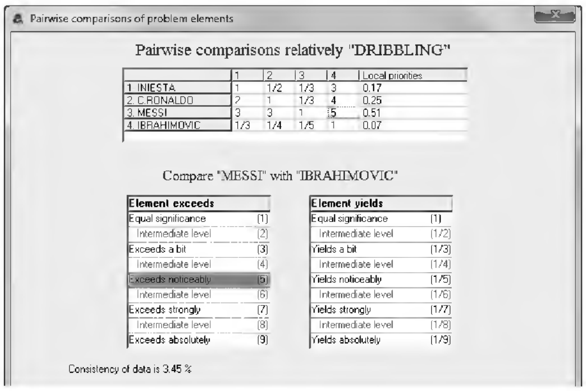

Fig. 9. Pairwise comparisons of alternatives

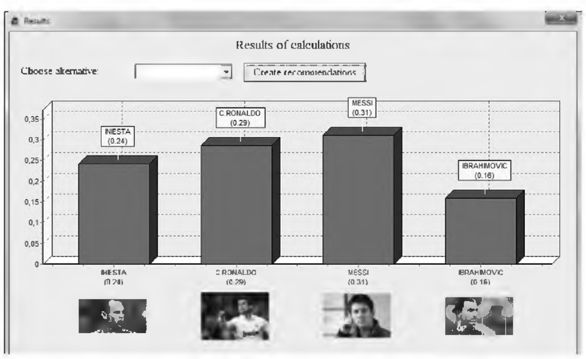

Fig. 10. Results of calculations

this alternative from the dropdown list at the top of a window and press the "Recommendations" button. The result is shown in Fig. 11.

Result of calculations is the list of 537 recommendations (1 line consists of 1 recommendation) for alternative "Iniesta", shown in the upper part of a window. Any of them guarantees to alternative "Iniesta" a victory.

Columns of each recommendation are average alternatives concerning which it is necessary to improve the state.

In brackets the numbers from certain range are output. They show the previous and desirable state of an alternative. So, Fig. 11 demonstrates the recommendation No. 10 according to which the alternative "Iniesta" should improve: A) his athleticism qualities a bit concerning his current state (from 1 to 2); B) his speed qualities a bit concerning his current state (from 1 to 2); C) his playmaker qualities a bit concerning current state of alternative "Messi" (from 1 to 2).

In the given calculation the recommendations for alternative "Iniesta" are constructed on the analysis of all 7 criteria. But the system allows (see the left lower part of the given window) user to choose not everything, but only certain criteria for development of recommendations. It is reasonable to select the criteria allowing alternative to improve its current state in the simplest way. In addition to selecting criterion the system gives opportunity to specify deviation level on which the alternative can improve the state compared with the previous one by this criterion.

If there are many recommendations, the system allows to arrange them on one of three parameters, namely: by resulting index of efforts (cumulative efforts); by weighed efforts; by the number of steps (see Fig. 11, upper right corner). They correspond to formulas (1), (3) and (2), respectively (described in the Chapter 2). To arrange the recommendations

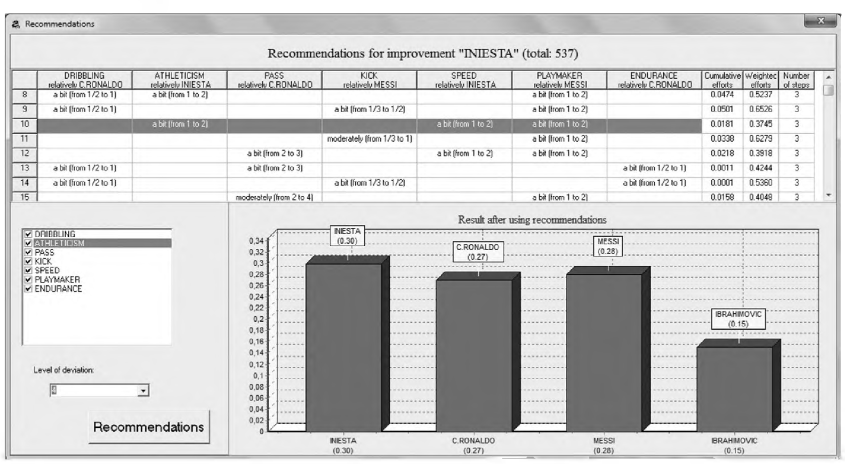

Fig. 11. Results of calculations for losing alternative ("Iniesta") after improvement

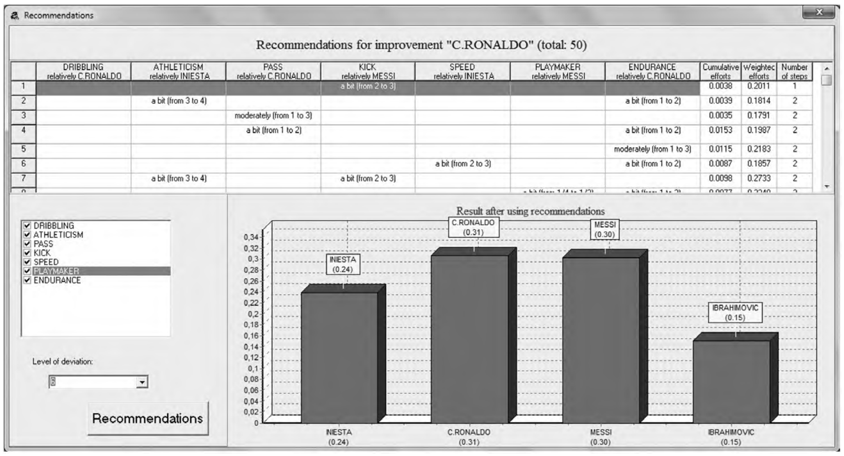

Fig. 12. Results for losing alternative ("C.Ronaldo") after improvement

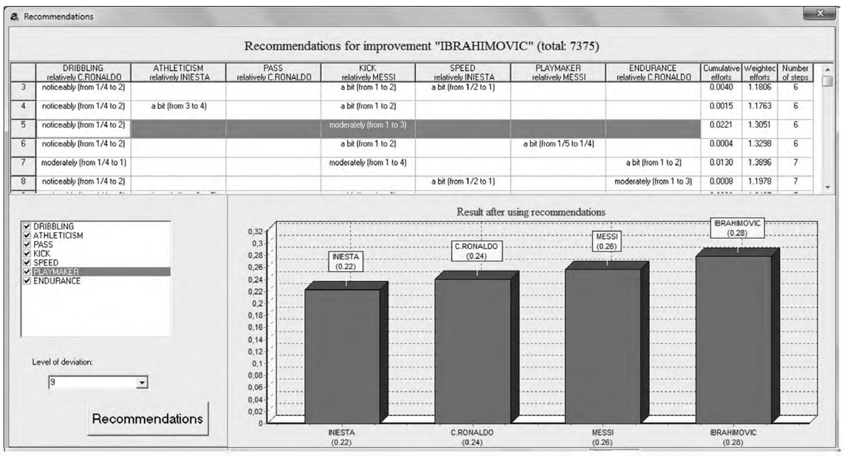

Fig. 13. Results for losing alternative ("Ibrahimović") after improvement

it is sufficient to click on a desirable column and then the recommendations with the smallest values of this parameter will be first to output.

In Fig. 12–13 the recommendations for improvements for losing alternatives "C.Ronaldo" and "Ibrahimović" (different from "Iniesta") are shown as example of demonstration of analogical usage of software system.

Certainly, the final decision of recommendations selection is accepted by the person. But the system provides to the person very effective tool not only for the analysis of a current state of alternative, but also for evaluating perspectives of its improving in the future, creating "guidelines for actions". It is very important that these recommendations are the most specific, at least insofar as it is generally possible in solving of semistructured multicriteria optimization problems.

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ПРОГРАМНА СИСТЕМА ДОСЛІДЖЕННЯ СЛАБОСТРУКТУРОВАНИХ ЗАДАЧ БАГАТОКРИТЕРІАЛЬНОЇ ОПТИМІЗАЦІЇ

Розроблено систему підтримки прийняття оптимальних рішень при розв'язанні слабоструктурованих задач багатокритеріальної оптимізації, яка може бути корисна особам чи колегіальним органам, що приймають відповідальні рішення. Існуючі на сьогодні програмні системи, які розв'язують такого класу задачі, обмежуються лише пошуком найкращої альтернативи, тоді як запропонована система також (крім вирішення цієї задачі) дозволяє розробити інструкції («настанови до дій») для будь-якої альтернативи, що програла, дотримання яких гарантуватиме даній альтернативі перемогу.

Ключові слова: слабоструктуровані задачі, багатокритеріальна оптимізація, метод аналізу ієрархій, критерії, альтернативи.

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ПРОТОКОЛИ ЕЛЕКТРОННОГО ГОЛОСУВАННЯ

У статті розглянуто основні положення концепції електронного уряду, протоколи електронного голосування та проаналізовано їх щодо надійності та можливості програмної реалізації і впровадження.

Ключові слова: електронний уряд, електронне голосування, протоколи електронного голосування, програмні системи підтримки електронного уряду.

Вступ

Наразі системи підтримки електронного уряду є важливою складовою комунікації урядових структур та громадян держави. Зростає зацікавленість України у пришвидшенні донесення інформації до її громадян і підвищенні надійності спілкування. Прикладом є впровадження електронного оподаткування та подачі податкових звітів [1].

Важливою складовою у системі електронного уряду є електронне голосування. Хоча про системи віддаленого голосування почали говорити відносно недавно (можна сказати, що ця галузь є надбанням XXI ст.), але вони стрімко набирають популярності як у бізнесі, так і в урядових структурах. Однак існує низка суттєвих відмінностей між вимогами до проектування корпоративних систем голосування та систем голосування загальнодержавного масштабу. Основними критеріями, з одного боку, є підвищені вимоги до захищеності такої системи, а з іншого – забезпечення конституційних прав громадян таємниці голосування. Відомі приклади застосування інтернет-голосування для проведення регіональних та загальнодержавних виборів. У 2007 році Естонія провела перші парламентські вибори, де електронне голосування прирівнювалось до традиційного голосування на виборчій дільниці.