Expert Group Formation for Task Performing: Competence-Based Method and Implementation

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***Abstract*—The problem of searching a group of experts to solve cross-domain problems remains an important problem in many applications. An automated expert search can make human resource management more efficient and reduce the number of problems. The paper presents a method of expert group formation for joint task performing. This method checks each available expert who can participate in task performing and sifts out the least effective of them. During this checking it forms several groups of experts and sorts them by their optimality based on their proficiency level, cost and influence of experts on each other. The method is implemented and approbated in a competence management system developed earlier.**

I. INTRODUCTION

All enterprises, institutions, and organizations have experts who are knowledgable or who master in-depth skills in specified areas [1]. They perform most part of the work, so the task of the human resource managers is to properly assign experts for each task. Manual assignment can be inefficient because it requires a lot of time and the human factor can cause errors. This becomes more complicated when tasks require the participation of many experts who are skilled in different areas. An automated experts search can make this process more efficient and reduce the number of incorrect assignments.

A major challenge within any organization is managing the expertise of formal or informal groups of people within the organization such that groups with expertise in a particular area can be identified. Finding a group or a team that harbors expertise is different from first finding an expert and then sorting out to which team the expert belongs [2]. On the other hand, a mapping of the knowledge levels and profiles of each member of the organization is required for implementation of the intelligent selections [3]. Human resources planning can assist in the rational assignment of professionals into business and professional capabilities of the staff [4].

The method proposed in the paper is aimed at solving this problem. It forms an expert group that has experts who can jointly perform a given task. The method is based on ontology-based competence representation of expert network participants [5]. The proposed method considers many aspects: requirements of the task that needs to be performed; experts' skills and their proficiency levels for each specialized areas; time, which expert could spend for task performing; cost for each expert's work; the degree of psychological influence of experts on each other. The method proposes several options and their optimality coefficients to choose from. Each of these options is a formed expert group sufficient for the task. Optimality coefficient of such a group shows efficiency of it in terms of criteria described above. These options and optimality coefficients make the process of experts assignment more informed and therefore more effective.

The method is implemented for the competence management system developed earlier [5], [6]. To evaluate the method, information on the real experts and tasks have been accumulated in the system. The implemented method formed different expert groups for each of tasks. Each of these groups was able to perform the given task. The groups have been automatically sorted by decreasing the optimality coefficient in order to facilitate group selection. The paper enhances the previous author's paper [7] in the method development and implementation.

The rest of the paper is organized as follows. Section 2 considers the related works in the area of expert searching. The third section is devoted to the method description. The implementation of the method is represented in details in the fourth section. The conclusion summarizes the paper.

II. RELATED WORK

Paper [1] presents a comprehensive survey on the state-of-the-art approaches on the topics of the expertise resource selection and expertise modeling. Authors consider various ways to model expert database and to search for experts, such as: meta databases to store expertise of employees and personal profiles of the experts as an extending of these databases; automatically discovering the up-to-date expertise information from secondary sources; a referral web that consists of a group of people sharing the same interests or professions; generative probabilistic models, voting models, graph-based models, and hybrids of these models. The paper describes the main principles used in these approaches, their pros and cons. However, the authors note that very few research works have been conducted on problem of finding a group of experts to solve cross-domain problems, and this remains an important problem in many applications.

Paper [8] considers trouble ticket management and proposes an expert collaboration network model and the corresponding expert recommendation algorithm for automated skilled expert assignment. Proposed model presents experts in form of an expertise and social profiles. An expertise profile represents professional knowledge of an expert and consists of two aspects: one or more specialized areas and proficiency level of an expert in each specialized area. Social profile represents social knowledge of an expert and describes the collaboration capacity of an expert. Expertise and social profiles of experts base expert collaboration network.

Proposed expert recommendation algorithm contains a two-stage expert finding process. In the first stage, an initial expert whose proficiency level is not less than ticket's difficulty level is recommended. Depending on the policy, this initial expert may have minimum professional ability or maximal professional ability, or this expert can be chosen randomly. The second step applies if the initial expert failed to solve the ticket. In this case a next-step expert recommendation algorithm finds the best expert from the initial expert's collaborators in the expert collaboration network. This process continues until the ticket is solved or amount of recommended experts is more than maximal length of the routing path. If the recommendation algorithms could not help to find an expert who can solve the ticket, then manual ticket routing is applied.

The described model is effective for expert search, which takes into account their professional and social knowledge. Authors showed that the combination of the model and recommendation algorithm can be used to avoid manual routing decision with a high precision accuracy and resolution success rate. But the described algorithms cannot be applied to other tasks except ticket routing because they assume that experts could only resolve tickets which belong to one of their specialized areas.

Paper [9] focuses on providing decision support for IT case management systems by automated recommendation of the best steps and experts to resolve an open case, based on the knowledge of past similar cases. The main components of the system are the automated discovery of annotated models and the recommender. An annotated step-flow-model discovery component analyzes the previous cases present in a repository and builds a step flow model. In this model each step is annotated with the metadata information of previous cases that took that particular step. The step recommendation component uses a discovered step flow model corresponding to the type of the open case and finds the best matches of paths in the model. After this it recommend next steps for the open case and also recommend experts who have performed these steps during the resolution of a past case.

The related works analysis showed that the problem of expert group searching remains unresolved and the development of a method for solving it is an important task. Expertise profiles that represent experts' professional knowledge is an effective tool for storing and using information about competencies of the experts. Social relationships between the experts are also important to consider.

III. Proposed method

The developed method is aimed at forming a group of experts to jointly perform a task. A task should contains a set of requirements which describe a skill and its proficiency level needed to perform a particular job. The output of the method is a list of options, each of which is a group of experts that covers all the task requirements. Requirement is considered to be covered by the group if at least one of the experts in the group has a skill contained in this requirement.

The proposed method is described by the reference model, the algorithm and the mathematical model. They are described in the section below.

A. *Reference Model*

The reference model that describes the relationships of the terms using in the method for expert group formation is shown in Fig. 1.

Each expert is represented by a profile. It contains service information about the expert and competencies which show what the expert can do. Each expert's profile has at least one competency; more often it has about 10 competencies. Each competency indicates a skill that the expert has and its proficiency level. Thus, an expert's profile shows the professional competence of the expert.

Each task contains a description and requirements which show what needs to be done to complete the work. Task can contain one or more requirements. Each of them indicates a skill that is necessary for the task and its proficiency level.

The set of skills which are contained in the competencies and requirements is the same. Each one of the skills has description about it and its maximal proficiency level.

B. *Description of the algorithm*

An activity diagram that describes the algorithm for expert group formation is shown in Fig. 2.

All formed groups are saving in decision list which is created at the beginning of the formation. For this purpose all available experts are checked for compliance with several conditions.

At first, all the experts who do not have the skills required for the task are removed from the experts list. Experts who have at least one skill that is required for the task and is not covered by the current group are added to this group. Such experts are also removed from the expert list, so they will not be added several times. If an expert has required skills but they are covered by the current group, this expert will be added later, when the group will be changed.

When all the task requirements are covered by the current group, which means that for each requirement there is an expert in the group who has the corresponding skill, this group is added in the decision list. The optimality coefficient is calculated for the formed group by the formula (15). This coefficient is used to compare different group option with each other.

After adding the group to the decision list, the least effective expert is removed from the current group and all experts who were not removed from the expert list are checked again. The least effective expert is the one without which the group's optimality coefficient is the highest.

If the expert list is empty or all experts in it are checked, but there are task requirements uncovered by the current group, then formation is considered complete. If the decision list is empty at this point, then the task is considered impossible.

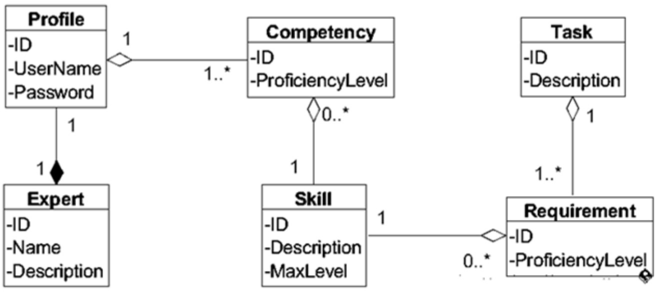

Fig. 1. A reference model of the method for expert group formation

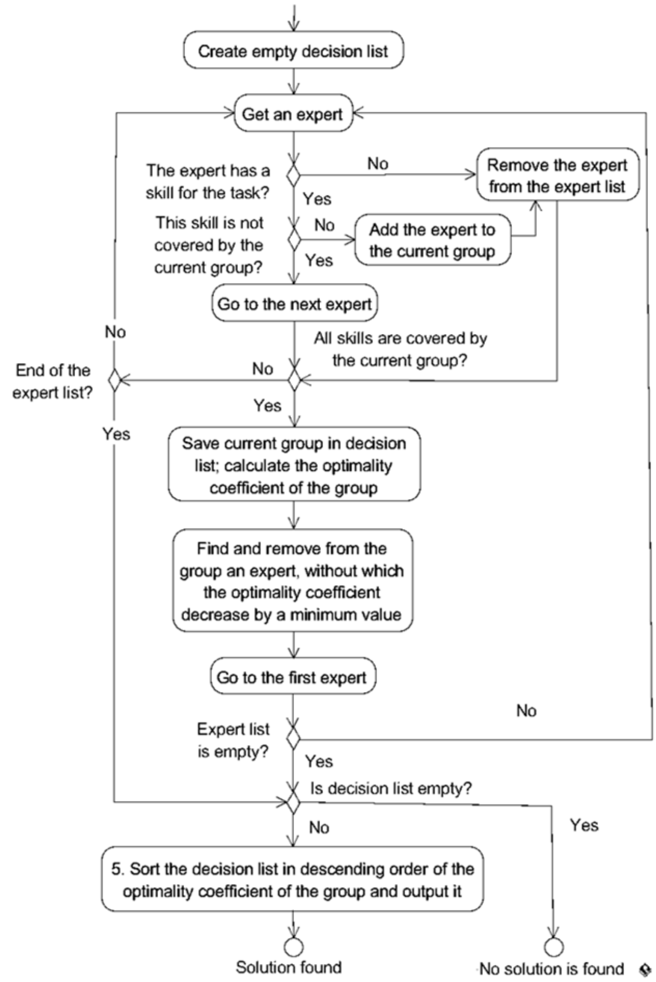

Fig. 2. An activity diagram of the method for expert group formation

Otherwise, all decisions in the list are sorted by decreasing the group's optimality coefficient.

C. *Mathematical model*

The list of skills that experts can have is a set, see (1).

$$S = \{S_n, n=1..N\}, \quad (1)$$

where N is the number of skills. Also, each skill S_n corresponds to the maximum proficiency level of SM_n. The task that is needs to be done is formally defined, see (2).

$$T = \{t, \tau, C_{max}\}, \quad (2)$$

where t is the following set, see (3).

$$t = \{t_n, n=1..N\}, \quad (3)$$

in which t_n – is the proficiency level required for S_n; τ is the following set, see (4).

$$\tau = \{\tau_n, n=1..N\}, \quad (4)$$

where τ_n is the work time that the expert who has skill S_n, should spend to complete the job associated with this skill; C_{max} is the maximum cost of works for the task performing. The list of available experts is a set, see (5).

$$P = \{P_m, m=1..M\}, \quad (5)$$

where M is the number of available experts. The experts also have the following characteristics. Experts' competencies are represented as follows, see (6).

$$L = \begin{pmatrix} l_{11} & \cdots & l_{1N} \\ \vdots & \ddots & \vdots \\ l_{M1} & \cdots & l_{MN} \end{pmatrix}, \quad (6)$$

where l_{mn} is the proficiency level on skill S_n of expert P_m. The work cost of the experts is represented by a matrix, see (7).

$$C = \begin{pmatrix} c_{11} & \cdots & c_{1N} \\ \vdots & \ddots & \vdots \\ c_{M1} & \cdots & c_{MN} \end{pmatrix} \quad (7)$$

where c_{mn} is the cost of applying skill S_n of expert P_m per hour of work. Reconcilability of experts is presented in the form of a matrix, see (8).

$$R = \begin{pmatrix} r_{11} & \cdots & r_{1M} \\ \vdots & \ddots & \vdots \\ r_{M1} & \cdots & r_{MM} \end{pmatrix}, \quad (8)$$

where r_{ij} is degree of influence of expert r_i on expert r_j, $r_{ij} \in$ ($\frac{1}{10}$ to 10). If an expert does not have any influence on another (neither positive nor negative), then its degree of influence is equal to one. If the influence is negative, then the degree of influence is less than one (e.g., if $r_{12} = \frac{1}{2}$, then the first expert worsens the productivity of the second twice); if the influence is positive, then the degree is more than one (if $r_{12} = 2$, then the first expert improves the performance of the second twice).

The formed groups are contained in the decision list that is represented as a binary matrix, see (9).

$$D = \begin{pmatrix} d_{11} & \cdots & d_{1M} \\ \vdots & \ddots & \vdots \\ d_{F1} & \cdots & d_{FM} \end{pmatrix}, \quad (9)$$

where F is the number of decisions found. The lines represent decisions, columns represent available experts. The value of cell d_{fm} at the intersection indicates whether expert P_m participates in decision d_f.

The group's optimality coefficient is calculated on the basis of the group cost, aggregate competence of experts, and reconcilability of experts in the group. The group cost is calculated by the formula, see (10) and (11).

$$Cost = \sum_{i \epsilon K} \sum_{j \epsilon N} x_{ij} c_{ij} \tau_j, \quad (10)$$

$$x_{ij} = \begin{cases} 1, l_{ij} \geq \max_{j \epsilon N}(l_j) \ and \ t_j > 0 \\ 0, otherwise \end{cases}, \quad (11)$$

where K is the number of experts in the group.

Thus, if the expert has the skill required to perform the task better than the other experts in the group (i.e., his proficiency level on this skill is not lower than its maximum proficiency level among all the experts in the group), then the cost of applying this skill by this expert is multiplied by the time of work required for the skill and is added to the total sum.

Aggregate competence of experts is calculated by the formula, see (12).

$$Levels = \sum_{i\epsilon K}\sum_{j\epsilon N} x_{ij}\frac{l_{ij}}{t_j} - \sum_{j\epsilon N} y_j \quad (12)$$

$$y_j = \begin{cases} 1, t_j > \max_{j\epsilon N}(l_j) \\ 0, otherwise \end{cases}, \quad (13)$$

Thus, if the expert has the skill required to perform the task with better proficiency level than the other experts in the group, then its proficiency level on this skill is divided into the proficiency level required by the task and is added to the total sum.

The amount of the uncovered task requirements is deducted from the aggregate competence of experts. This amount is equal zero for the groups from the decision list because they are complete, but it is needed when the least effective expert in the group is calculated.

Reconcilability of experts in the group is calculated by the formula, see (14).

$$Reconcilability = \prod_{i\epsilon K}\prod_{j\epsilon K} r_{ij} \quad (14)$$

Thus, the degrees of the experts' influence in the group are multiplied among themselves. The result shows how the composition of the group as a whole affects its performance.

The group's optimality coefficient is calculated by the formula, see (15).

$$O = \frac{Levels * Reconcilability}{Cost} \quad (15)$$

Thus, the optimality of the experts' group is directly proportional to the aggregate competence and reconcilability of the experts in the group and inversely proportional to the cost of work of the experts' group.

With the group's optimality coefficient, the time required to perform the task by the community formed is calculated for each formed group. This time is calculated by the formula, see (16).

$$Time = \sum_{i\epsilon K}\sum_{j\epsilon N} x_{ij}\tau_j \quad (16)$$

Thus, if the expert has the skill required to perform the task with better proficiency level than the other experts in the group, the time that he has to spend to perform the part of the task associated with this skill is added to the total sum.

D. *Algorithm complexity*

To evaluate the complexity of the algorithm, the worst scenario should be considered:

- The task requires all the skills;
- Experts are sorted in such a way that adding the first expert in the group will make other experts checking required for completing the group;
- After every removing of the least effective expert from the group only the last available expert can complete the group.

In this case after adding the first expert in the group, each expert will be added in the group and then removed from it while other experts will be checked. The complexity of this procedure is equal to M^2. Removing of the least effective expert from the group requires calculating optimality that depends on N because in the case under consideration the groups has one or two experts. Checking of each expert is also depends on N. Thus, the algorithm has complexity $O(M^2 \times N)$.

IV. Implementation of the Method

This Section's focus is the implementation of the proposed method in the competence management system. It contains the description of the implementation process and the results of the method approbation.

A. *Competence management system*

The method described in this paper was implemented in competence management system of Technopark of ITMO University in Saint-Petersburg, Russia.

The experts are represented in the system as residents. A resident can present a company, organization or person who provides some services. Each resident has a profile that contains information about the resident, its competencies and their evidences. An example of the resident profile is shown in Fig. 3.

Information about a resident contains the name of the organization or person, a website, a brief description and contact information. Competency is a set of skills, knowledge and behavioral aptitude in a specific context and with a certain proficiency level. A certificate or work experience can be evidence of the proficiency level. The set of competencies defines a competence, which can also be confirmed by evidence.

Each task also has a profile in the system. It contains a task description and a list of required competencies. An example of the task profile is shown in Fig. 4.

B. *Entering data into the competence management system*

The real data of about 35 different experts have been accumulated to test and evaluate the method of expert group formation. For this purpose, three- stage procedure of entering data was initiated.

At the first stage, the competence management system was introduced to the residents of the Technopark. They were told the purpose of the system, its functionality, what data is

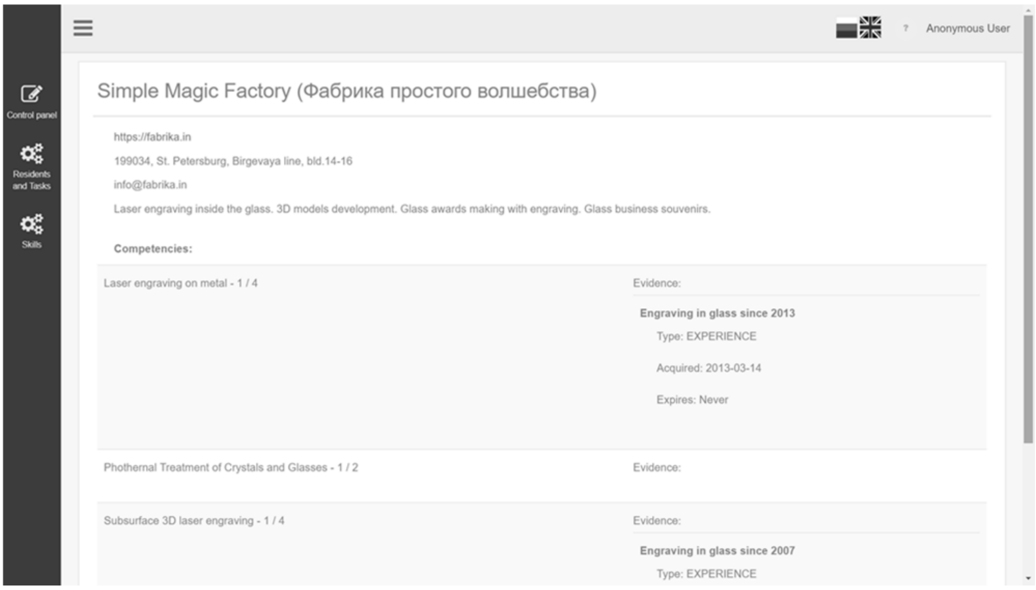

Fig. 3. An example of the resident profile in the competence management system

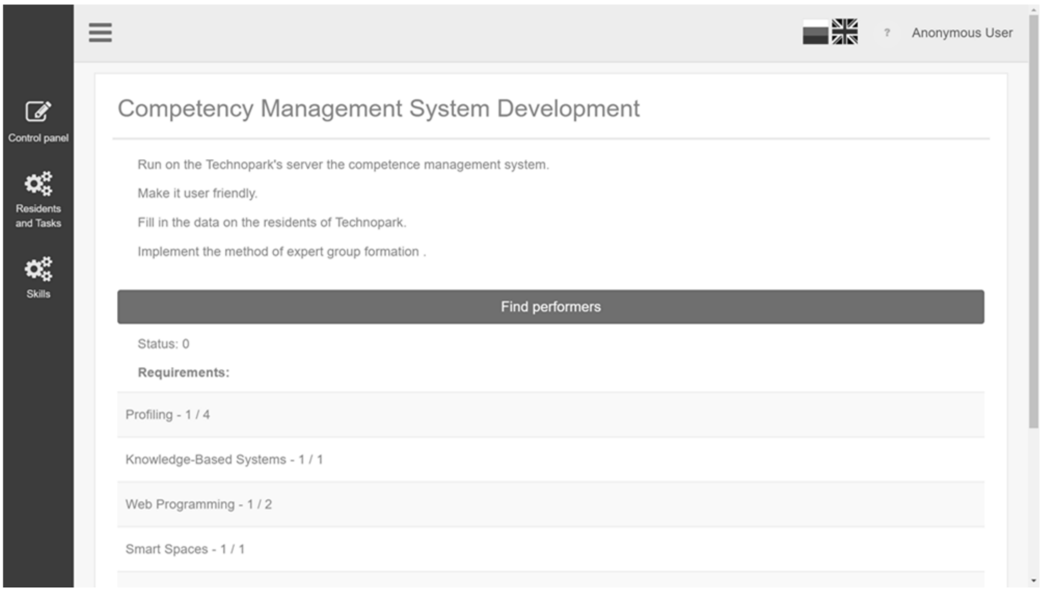

Fig. 4. An example of the task profile in the competence management system

required and how to enter it. To do this they were given a few days. At the second stage the entered data was checked for errors and relevance. Missing information was added in the profile, if necessary. At the third stage, the amendments were adopted or adjusted by the residents, and the proficiency levels were indicated.

As a result of the described procedure, complete data on real experts and their competencies was introduced into the competency management system. A several tasks and information about it was entered in the system by the Technopark management. More than 30 residents and several varied tasks were sufficient to evaluate the method.

C. *The method implementation and evaluation*

The method was implemented in the system as a feature for a task profile. Programming languages Java and JavaScript, as well as Spring framework were used for implementation.

The appropriate user interface can be seen in Fig. 4. To find performers for the task, a task manager has to press the corresponding button in the task profile.

An example of the result of the method is shown in Fig. 5. It contains information on the task and all the options of the expert groups found by the method.

Each option contains a list of residents who can perform the task, their competencies required for the task, the relative optimality coefficient of the group, the cost of each resident and the total cost of the group. The total cost of the group is calculated by the formula, see (10). The relative optimality coefficient of the group is calculated by the formula, see (17).

$$O(rel)_i = \frac{O_i}{\max\limits_{i \epsilon F}(O_i)} * 100\% \tag{17}$$

Thus, the relative optimality coefficient of an option is equal to the optimality coefficient of this option, divided by the greatest optimality coefficient among the found options. These relative optimality coefficients are convenient for comparing options with each other.

To test and evaluate the method, it was applied for each task in the system under the direction of the task managers. Each of them was asked about the satisfaction of each option. In the most cases, the method result matched the task manager's expectations, that is, the manager would assign one of the expert group proposed by the method to the task. This allows to conclude that the method works properly and efficiently.

V. Conclusion

This paper presents the research in the area of expert searching for joint task performing. The method proposed in this paper considers many aspects to form an expert group that is able to efficiently perform the task. Moreover, the method proposes several options of the expert groups to choose from in order to make experts assignment process more informed.

The method was implemented evaluated in the competency management system. The result of the method on real data and the survey of the task managers showed that it works properly and efficiently.

For future work, the method can be adopted for other systems in order to be applied for different companies and organizations. Taking into account previous projects to recommend experts for the current one can also improve the method efficiency.

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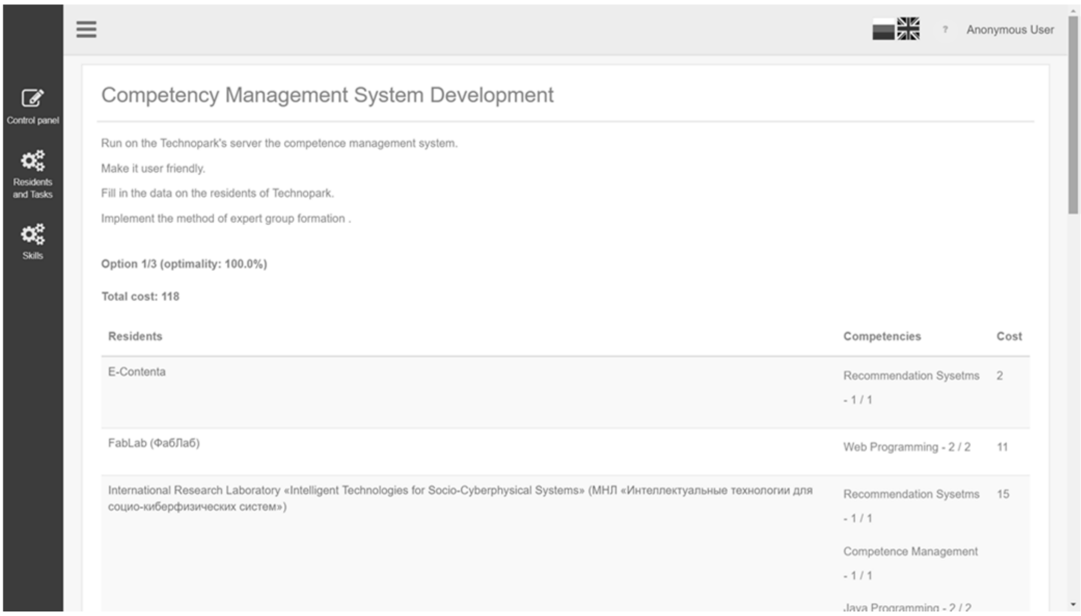

Fig. 5. An example of the method output