# Mathematical Modeling in Adaptive Corporate Training

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*Abstract*—**The method of forming the content of individual training courses in the corporate training system is proposed. The method is based on the use of a mathematical model to represent the content of the corporate knowledge base. The model is a cognitive map of the corporate knowledge base, representing information units of this base and logical connections between them. The vertices and arcs of the cognitive map have a number of quantitative characteristics used in the process of constructing models for the content of training courses. Based on this model, models of positions and models of employees of the organization are built. It is shown how by comparing the qualification requirements of a certain position with the set of competencies of a particular employee, to build a model of the content of an individualized training course adapted for this employee. The algorithm for solving this problem is developed. Also the optimization problem statement of planning the content of an individual training course is presented with a given restriction on the time of its study. The structural-functional model and the software module architecture for the automated construction of the content model of such a training course are presented.**

## I. Introduction

Corporate training (CT) is a process of improving the professional knowledge and skills of employees carried out to improve the efficiency of the work at the enterprise. The main objectives of the CT are: creation of a personnel reserve, increasing the effectiveness of employees' work, developing a corporate culture, ensuring a sustainable competitiveness of the company in the market. The tasks solved by the CT system include adaptation of new employees, technological training related to professional knowledge and skills, training on corporate competencies.

Inclusion of CT in the personnel management system allows you to quickly carry out professional preparation in accordance with the constantly changing external requirements and internal needs of the organization; the formation of employees not only with new professional knowledge and skills, but also with a special corporate culture, manifested in the interaction of staff within the company, as well as in working with clients and partners.

CT is focused on the practice of solving professional problems. This feature manifests itself in its forms, which, as a rule, have a pronounced practical orientation.

The main forms of CT include distance learning, training with a teacher and podcasting. When training with a teacher, classes can take place in the form of lectures, seminars, trainings, business games. Moreover, training can take place not only in a group format, but also individually.

Using distance form of CT, students have the opportunity to learn at the territorial distance from the teacher or independently using e-learning applications and at a convenient time. Podcasting refers to the most high-tech form of CT. With this form, the Internet is actively used. In the network places audio and video podcasts, creates blogs on the topics of training, record the lecture material with the reference to the visual inspection of the instructions subject. Knowledge bases (WIKI) with which students work independently when information is needed for them are created [1], [2].

The choice of the specific method of teaching is determined by the goals of the training, the category of trainees, the capabilities of the organization.

Corporate universities are the most developed form of educational structures in CT. Among Russian companies such units have Gazprom, Sberbank, Norilsk Nickel, IBS, Diasoft and a large number of other successful private and state companies [3]. The corporate university level systems ensure to conduct a regular planned educational process using pre-designed training courses and other specially designed materials.

Along with this, in the activity of any organization there are situations when there is a need for the rapid development by a particular employee a specific new set of professional competencies. These situations are connected with such personnel processes as hiring new employees, moving employees from one post to another, changing job responsibilities, requirements for knowledge and skills of employees occupying certain positions, and so on.

E-learning tools are actively used in CT, allowing you to reduce the cost of training and retraining of employees, and to speed up these processes. The software systems used to develop, manage, and distribute e-learning materials are divided into two types: Learning Management Systems (LMS) and Learning Content Management Systems (LCMS) [4].

The main functions of LMS are related to the administration of the learning process and the provision of interaction between trainees and teachers and also between each other. Also, these systems provide a basic set of opportunities for preparing training courses and provide work of trainees with educational materials The main functionality of LCMS is related to the development and use of electronic training courses.

There are a lot of LCMS / LMS systems developed for higher education and for corporate clients. Among the systems that specialize in corporate training, there are SuccessFactors Learning (http://www.successfactors.com/en_us/solutions/bizx-suite/talent-solutions/learning.html), Train @ Work (http: //ww1.saba .com / mx / services / train-at-work /) and others.

In Russia, several projects are being developed, among them: SDA"PROMETHEUS", the corporate system of management of remote learning ShareKnowledge (Competentum, http://www.competentum.ru), WebTutor - a system for automating business processes related to the systematization and storage of knowledge, selection, evaluation, testing and training of personnel and others.

Firm 1C has released a line of software products "1C: e-learning", designed to organize and conduct electronic and mixed training in commercial organizations, educational institutions and budget institutions (http://v8.1c.ru/elo/). For now, the product line presents: a solution for the organization, conduct and management of mixed education, a means of supporting the electronic training of the traditional (classroom) educational process of technical schools, colleges and universities, a tool for developing e-courses, conducting training and analyzing its results, and a tool for developing electronic tests, organization of training, testing and analysis of its results.

Despite existing developments, the task remains to create systems for the development of corporate and individual training courses that are quickly adapted to the current needs of the organization, which may be in demand among managers, developers of distance learning programs and staff of educational institutions.

It seems that it is possible to provide the functional advantage of a new LCMS-type system for corporate training in comparison with the existing ones by using formal logic-mathematical models to present and analyze the content of the educational material used in course design. Mathematical formalization of the planning task and managing of the training course content allows you to improve the course quality in terms of the content logical organization, the ratio effectiveness of learning outcomes study time costs and adaptability to specific goals while using the course.

## II. Corporate Knowledge Base

CT within the organization (internal corporate training), as a rule, uses short duration courses, the content of which must be systematically updated. In addition, for effective learning, it is necessary to use training courses that can be adapted to the level of knowledge and preparation of a particular employee and the specific purpose of his training.

The basis for building intracorporate training courses is the information array formed during the functioning of the organization, consisting of various kinds of documents, databases of information systems and other information materials related to the activities of this organization. The whole complex of information of this kind forms a corporate knowledge base (CKB) of a specific organization.

CKB is represented explicitly as part of an organization's intangible asset, its intellectual capital. The active, systematic use and development of this capital is one of the main factors for the successful operation of the organization. As noted in [5], knowledge management is a relatively independent type of management organization that aims to create, transfer, distribute, store, use and develop knowledge, as well as the formation and using the intellectual capital.

The content of a typical CKB is substantially heterogeneous because it includes information materials of various types, volumes, forms of representation, and the like. But all the various components of the CKB can be considered as information units, connected by a different relationship. To create intracorporate training courses for these information units, we will use the unified denomination of concepts. Some of the concepts may be in relation to the previous-subsequent in the sense of the order of their study and development.

This approach allows the following model of network models in the form of cognitive maps to be used to represent the CKB content model. Cognitive maps were proposed as a way to describe complicated systems and processes. the state and development these systems is determined by a set of factors (concepts) that affect each other. If one factor affects the other one, then on the cognitive map factors are connected by an arc, which marks the feature and degree of this influence [6]. Examples of the use of cognitive maps for modeling in the study of economic and social processes are contained in [7].

In our case, the concepts of the cognitive map will correspond to the information units of the CKB. The arcs that connect the concepts are a reflection of the sequence in which the information units corresponding to the concepts should be studied.

Concepts of the cognitive map are supplied with a number of indicators, such as the importance of the concept, the complexity of its study, the time required for studying, and others. Arcs are assigned positive weights, showing how much information from one concept, is used in the study of another.

## III. Structural and Functional Model of the Formation of Individual Training Courses

The proposed approach to the formation of the content of individual training courses (ITC) is based on a comparison of the requirements for knowledge, skills, competences that constitute the qualification requirements of a certain position with a set of competencies of a specific employee newly recruited or transferred to this position.

At the same time, the missing (possibly) competencies are defined, the mastering of which will be the target setting determining the content of the training course intended for this employee. When the employee on the current position should acquire new competencies due to changes in job responsibilities and/or the emergence of new activities - this is another case of the need for such an individual course.

The implementation of this approach requires that the description of the qualification requirements for the positions and competences of staff be standardized with a description of the CKB content. At the same time, qualification requirements and competencies should be adequately reflected in the content of the CKB, from which the content of the training courses is formed.

For this, it is proposed to use a set of models describing qualification requirements (job models), staff competencies (employee models), content of individual training courses (ITC models). All models are constructed in terms that are consistent with those used to represent the contents of the CKB. The appearance of new / changing qualification requirements in employee models should be preceded by an appropriate update of the CKB. The models of employees reflect only those competences whose content is presented in the CKB.

Thereby, to support the creation of individual training courses, a system is required to support and join use of all models. One of the variants of constructing such a system was proposed in [8]. Here we consider a structural-functional model that modifies and develops the functionality of this system.

The context diagram of the structural-functional model of such system is shown at Fig. 1.

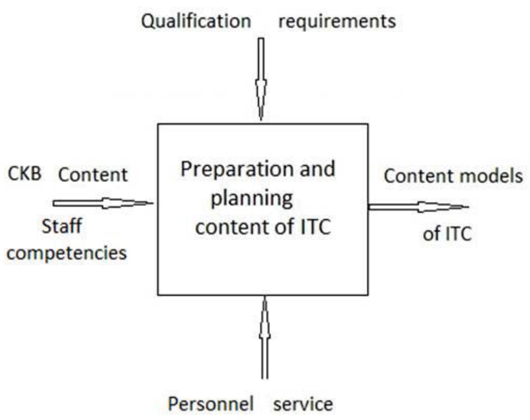


Fig. 1. Context chart

In accordance with the method of constructing structural-functional models, the input information of the system is divided into initial data and control information. Here, as the initial data for the formation process of ITC , information on the contents of the CKB and information on the competencies of the personnel of the organization and the newly recruited staff are considered.

Qualification requirements based on professional and corporate standards, business rules, technological regulations and other information presented in job models play the role of management information in this process.

The decomposition of the context diagram in accordance with the approach described above for the planning of ITC content is shown in Fig. 2. The diagram in this figure contains five functions with information links between them.

The function "Managing employee models" provides creation and update of models employees that contains information about the components of competence knowledge and skills.

Function "Managing job models" provides the creation and update of models of posts representing the set of qualification requirements that define the competencies required to perform the job duties.

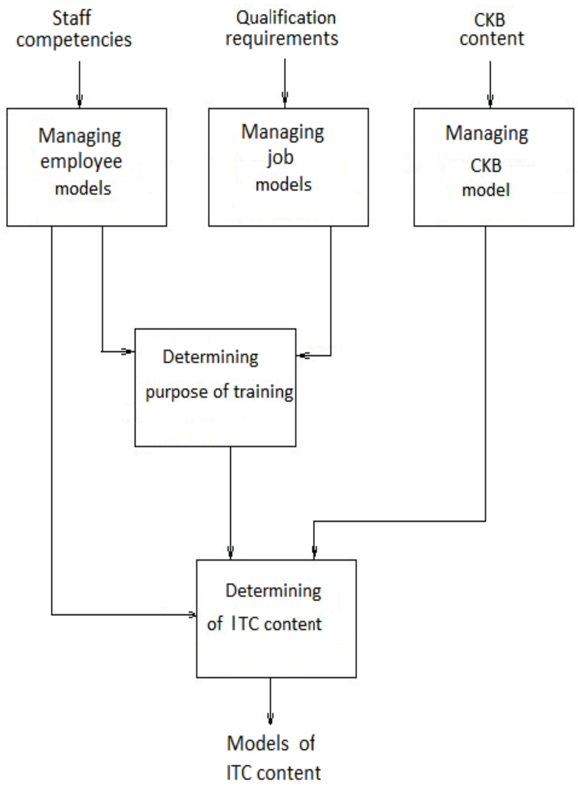


Fig. 2. Context diagram decomposition

The function "Managing CKB model" ensures the formation and maintenance a current status of the CKB model as a set of information units corresponding to various information objects forming the CKB filling. Information units of the CKB model can be linked by the "previous-subsequent" relations, reflecting the logical sequence of the study of the corresponding information objects when using these objects as educational material.

The function "Determining the purpose of training" provides identifying the missing competencies for this post from employee by comparing the qualification requirements of a particular position and the competencies of a particular candidate employee to this position. The list of such competencies is further used as a goal for the formation of the content of the relevant training course.

The function " Determining of ITC content" finds in the list of target competencies obtained by the function

"Determining the purpose of training", the corresponding target information units in the CKB model. Then this function adds information units from the CKB model to them, which are associated with the target prediction ratio. Finally, those competencies that already exist in the employee model are removed from the resulting set of information units.

The resulting set of information units of the CKB model, together with the existing "preceding-following" relationship between them, is a model of the ITC content. The content of the ITC itself is compiled in accordance with this model from information objects located in the CKB.

## IV. Architecture of the Software System

The architecture of the software system that implements the automated support of the described method of constructing ITC is presented in Fig. 3. It is determined by the structural-functional model presented above.

The system consists of sets of models of employees and positions, which form two databases, the CKB model and the base of the ITC content models created during the system operation and stored for possible subsequent use.

The level of system functionality required to maintain and use the models included in the system is provided by a set of control modules.

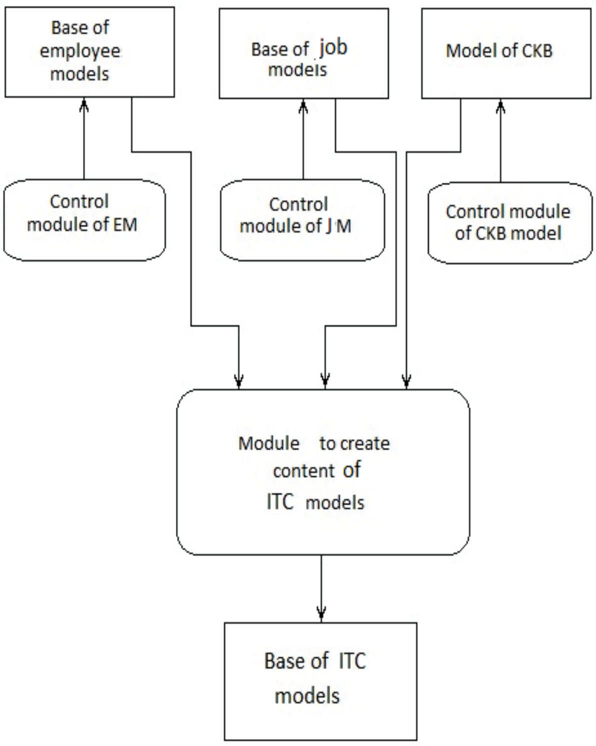


Fig..3. The architecture of the software system

The purpose of the CKB model management module is to input, edit and display the cognitive map – CKB content models. Editing includes: adding a new concept with establishing its links with other concepts of the model; updating the concept - changing its parameters and / or links; removal of the concept with a preliminary check of the possibility of this operation (no outgoing arcs).

The purpose of the module for managing job models is to enter, edit and display the job model. Editing includes: adding / removing a contract, updating a concept - changing its parameters.

The purpose of the module for managing personnel models is to enter, edit, display and delete the employee model. Editing includes: adding / removing the concept, updating the concept - changing its parameters.

The module for managing the ITC content model forms the learner model in accordance with the learning purpose, which is determined on the basis of the job model, and the current content of the employee model. The goal of learning is given by a set of concepts that need to be studied. The model of the trainee must contain three groups of concepts: target concepts and prerequisite concepts, defined by the CKBmodel. Concepts -prerequisites are concepts, the study of which must precede the study of the target concept in accordance with the cognitive map of the CKB.

Then the module for managing the ITC content model generates a cognitive map– the ITC content model containing the target concepts and which should be studied according to the trainees the concepts prerequisites. A set of such prerequisite concepts may not be complete, depending on the constraints imposed on the designed ITC and some other conditions. In this case, the problem of optimizing the ITC content can be solved.

## V. Mathematical Models and Algorithms

A common formal-logical basis for data representation is needed for the development of a software system that implements the ITC content design methodology, embedded in a structural-functional model. As shown above, numerical cognitive maps can be used as such a basis.

In the mathematical sense, the numerical cognitive map is a weighted oriented graph:

$$G = \langle C, U \rangle,$$

where $C = \{c_i\}$ is the set of vertex-concepts ($i$= 1,…,$N$ , $N$ is the number of concepts), $U = \{u_{i,j}\}$– is the set of arcs ($u_{i,j}$is the arc from the vertex $c_i$ to the vertex $c_j$).

By $w_{i,j}$ denote the weight of the arc $u_{i,j}$. We use the arcs between the concepts for designation of connections "subsequent-previous" between the concepts in this study. In accordance with it the value $w_{i,j}$ indicates the relative amount of knowledge of concept $i$ for to learn of concept $j$ ($w_{i,j} > 0$). . For an arbitrary pair of vertices c$c_i$,$c_j$) that do not have an arc $u_{i,j}$, we set $w_{i,j} = 0$.

The CKB model must be an acyclic graph for the correct use of the "subsequent-previous" relationship between the CKB concepts in the ITC content models, For the analysis of cognitive maps, a number of characteristics is used that can be used in modeling both the content of the CKB and the content of training courses. Among these characteristics are: the influence of one concept on another; influence concept on the card; influence of the map on the concept. To define these characteristics, the following notation is introduced:

$V_{i,j}$– is the magnitude of the influence of vertex i on vertex j. $V_{i,j} = 0$, if there is no path from *i* to *j*, otherwise $V_{i,j} = \prod_{s=0}^{m_l-1} w_{k_s^l k_{s+1}^l}$

where $k_0^l, k_1^l,..., k_{m_l}^l$ – are the numbers of the vertices forming the path *l* from vertex *i* to vertex *j* .

The degree of influence of vertex *i* on the map is defined as the averaged total effect on all the vertices of the map:

$$Q_i = \frac{1}{N}\sum_{j=1}^{N} V_{i,j}$$

.Similarly, the degree of influence of the map on the vertex is determined:

$$Z_i = \frac{1}{N}\sum_{j=1}^{N} V_{j,i}$$

The job models $D_f, (f = 1,2, \dots)$ and the employee models $S_e, (e = 1,2, \dots)$are subsets of the set of concepts of the CKB model: $D_f = \{c_{i_f}\}$, $S_e = \{c_{i_e}\}$, $i_f \in I_f$,$i_e \in I_e$, $I_f$,$I_e$are subsets of the set of concept numbers included in the CKB model.

Algorithm for constructing the ITC content model when assigning an employee with model number *e* to a position with model number *f*:

1) Identify the target concepts for learning $A_{f,e} = D_f \setminus S_e$
2) If $A_{f,e} = \emptyset$, then training is not required, otherwise go to 3).
3) Select from the cognitive map $G$ its part $G'$ , containing the target concepts$A_{f,e}$, their prerequisites (concepts for which there are paths connecting them to the target concepts) and the corresponding arcs.
4) Remove from $G'$the concepts contained in $S_e$, and all the concepts that are prerequisites for the deleted, along with the arcs incident to them.

The resulting cognitive map (if a set of target concepts is not empty) is the initial model of ITC content. This model can be corrected if necessary by adding or removing some concepts, including taking into account the degree of influence of the concepts on the cognitive map - course model.

At the same time, it is necessary to observe the logical correctness of the model in relation to the concepts "next-previous", which can be written in the form of condition

$$\sum_{i=1}^{N}(1 - x_i) \cdot \sum_{j=1}^{N} x_j \cdot V_{i,j} = 0 \quad (1)$$

where $x_i = 1$, if the concept *i* is included in the model, otherwise $x_i = 0$.

Another condition that can be set when planning ITC is the time limit for studying the course:

$$\sum_{i=1}^{N} x_i \cdot t_i \leq T \quad (2)$$

where$t_i$ is the learning time for the concept *i*.

If there are several candidates for one position, the search for the most suitable candidate can be carried out by the condition of the shortest duration of the ITC:

$$\min_{e \in K} \sum_{i \in I_e} t_i$$

where *K* is the set of model numbers of candidate employees, $J_e$is the set of concept numbers included in the ITC for the employee *e*.

If there are restrictions that do not allow to include all necessary concepts from the CKB model into the ITC model, the content planning task can be optimized. As the objective function to be maximized, in this case, the total significance of the concepts included in the course model will appear. By the importance of the concept here is the value $Q_i$- the degree of influence of the concept on the map-model of the course content. In the presence of such a characteristic of the concept as an estimate of its importance$P_i$, under the significance of the concept in the training course is understood the weighted sum $\alpha \cdot Q_i + \beta \cdot P_i$, where $\alpha, \beta$ - weighting coefficients.

In this case the objective function has the form:

$$\sum_{i=1}^{N} x_i(\alpha \cdot Q_i + \beta \cdot P_i) \to \max \quad (3)$$

The optimization problem with objective function (3) and constraints (1), (2) refers to the type of non-linear integer optimization problems. Heuristic algorithms widely use to find quasi-optimal solutions to solve this type of problem [9].

Because it is necessary to have target concepts entering the set $A_{f,e}$in the model of the content of the proposed ITC, the dimension of the problem is reduced. Therefore, practical possibilities of using the limited-search method are expanding.

The quantitative parameters are used for the elements of the above-described CKB content model in the form of the cognitive map. Among these parameters are such as: the weight of arcs of the cognitive map $w_{i,j}$, the time necessary to study the *i* -th concept $t_i$, the importance of the *i* -th concept $P_i$.

Obviously, the values of these parameters can not be measured or obtained by formal inference. These values should be set by the relevant experts in the form of expert assessments to use the CKB model. The expert assessments should be base on the previous experience of using the CKB and conducting CT in the organization.

## VI. Conclusion

At the model level, the design of the content of the training course can be viewed as a task of selection a number of concepts from the CKB, the study of which is necessary in order for the model of this employee to contain the model of a certain position as a subset of oneself. The method of mathematical modeling described above and the algorithm for constructing the ITC content model solve this problem.

From our point of view, the formalization on this basis of some corporate training procedures is the advantage of the approach proposed in the study.

It is clear, however, that the approach described above to the presentation of staff and job models as subsets of the CKB concepts is a significant simplification of the complex interrelated body of knowledge, skills, individual personal qualities of a person and the work performed by him / her.

Therefore, ITC, created according to the proposed methodology, will be as effective as the requirements for the competencies of employees can be formalized within the proposed models. First of all, this applies to fairly mass professions, job requirements for which are quite simply formulated and standardized.

Software implementation of models and algorithms in the form of a system with the architecture described in this paper allows to solve a number of problems in improving the efficiency of corporate training of certain categories of newly hired personnel and employees with changing responsibilities or transferred to new positions. Among these tasks, in particular, are:

- Reducing the cost of developing courses for internal corporate training and retraining by reducing development time and the ability to quickly modify existing courses.
- Improving the quality of training by adapting the content of the course to its specific purpose (training a specific employee for a specific position)
- Rapid updating of the CKB and consistent changes in job models, identification of required changes in employee models.

At present, the approach to design of ITC for CT is implemented in the form of a research prototype on the platform "1C: Enterprise 8.3" for the configuration of "1C: Corporate University" [10]. The obtained results and the made approbation allow to conclude that the use of such kind of system in the practice of corporate training is perspective.

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