Knowledge Transfer Platform Toolkit for Strategic Planning

Vitaliy Tsyganok [1,2,3], Anton Astakhov [1], Volodymyr Minas [1] and Maksym Konovaliuk [2]

[1] *Institute for Information Recording of National Academy of Sciences of Ukraine, Mykoly Shpaka str. 2, Kyiv, 03113, Ukraine*
[2] *National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Peremogy ave., 37, Kyiv, 03056, Ukraine*
[3] *Taras Shevchenko National University of Kyiv, Volodymyrs'ka str. 64/13, Kyiv, 01601, Ukraine*

Abstract

The research aims to help transfer knowledge from people who have it to people who need it to solve practical problems in specific domains. Applying this theoretical background is intended for strategic planning in various areas, especially in weakly structured subject domains. The knowledge transfer platform's technology and the knowledge transfer platform toolkit for strategic planning are proposed.

Keywords

knowledge transfer, strategic planning, goal dynamic evaluation of alternatives

1. Introduction

Using existing knowledge effectively is vital to humankind's growth, progress, and development. It is a same-level problem as a problem of accelerating the acquisition of knowledge in various fields.

The relevance of the work is determined by a significant amount of knowledge in weakly structured domains that are unregistered and unavailable for use at this moment. Moreover, a significant percentage of informal knowledge is owned only by certain specialists due to their unique experience and intuition. When building knowledge bases, it is advisable to use all available knowledge, both explicit (formalized) and implicit (which can be obtained in information networks and when contacting experts).

Convenient knowledge provision mechanisms are created based on the knowledge bases built by decomposing and structuring everyday problems using advanced decision support methods. There is a need to process knowledge of a different nature obtained from different sources: general verification for reliability, completeness, balance, coherence, the possibility of systematization, and generalization. There have yet to be fully developed methods and means to increase the application level of such knowledge. Therefore, the subject of the research is to create new methods, models, and software tools (knowledge transfer platform tools). They are used to obtain knowledge about a specific weakly structured subject domain, to process knowledge of a different nature, to formalize it, and to form a mechanism for using this knowledge by decision-makers in various fields.

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EMAIL: tsyganok@ipri.kiev.ua (V. Tsyganok); astakhov.anton97@gmail.com (A. Astakhov); vminas@i.ua (V. Minas); konovalyuk@gmail.com (M. Konovaliuk)
ORCID: 0000-0002-0821-4877 (V. Tsyganok); 0000-0002-9630-1101 (A. Astakhov); 0000-0003-4601-3790 (M. Konovaliuk)

2. Research Methodology

The technology of knowledge transfer is based on the group construction of a goal-oriented model of the system (subject domain) [1, 2], which is created by decomposing the main goal and considering the time and resource properties of the system components and the relations between them. The software toolkit allows knowledge engineers and experts to provide knowledge about the subject domain to create a model of the system.

The knowledge transfer platform can solve the problem of strategic planning [3] in several steps:

1. Define the main strategic goal.
2. Decompose the goal into sub-goals that affect the main goal in this subject domain.
3. Define non-decomposable goals within the competence of the decision-maker (DM).
4. Identify the required resources to implement each project.
5. Determine the duration and possible delay of each project.
6. Determine optimal resource allocation between the projects, which will maximize the efficiency of achieving the main strategic goal with a given financing.
7. Allow corrections to the strategic plan.

3. Strategic Planning

Since strategy is a way to achieve a specific goal, the concepts of strategy and goals are inseparable. Therefore, when building strategic plans, it is proposed to use the so-called goal-oriented approach. It is an approach to model the subject domain as a complex weekly structured system in the form of interconnected components or goals that affect one another.

3.1. Goal-Oriented Approach to Strategic Planning

When applying the goal-oriented approach, first, it is necessary to define the main goal that must be achieved during the implementation of the strategy. This strategic goal is usually formulated by decision-makers (DMs), such as state leaders, politicians, and businesspeople.

It is worth noting that the goal-oriented approach involves determining the characteristics of the main goal through the characteristics of other components of the system — goals that have a direct or indirect impact on the achievement of the primary goal.

3.2. Subject Domain Model

In strategic planning, assessing the goal's achievement level over time is essential. Therefore, the model of the subject domain is created considering this requirement.

The subject domain model is a directed graph of the hierarchy of goals formed due to the decomposition of the primary goal. Arbitrary influences (connections) between goals can be added to the graph model to increase the model's adequacy. Although the resulting graph has a hierarchical tree structure, it is generally a network.

The model has the following components: goals — vertices (nodes) of the graph, projects — vertices (leaves of the tree), and influences — arcs of the directed graph. All the listed components can be of different types and have different properties.

3.2.1. Goal Model

The main component in the system model is the goal. Goals are represented as graph vertices in the general model of the system. Goals are formed as a decomposition of the main goal and are essentially its components.

Two types of processes lead to goal achievement. Linear goal — when any progress in achieving the goal causes a change in the impact of this goal on other goals. Threshold goal — when the goal does not impact other goals until the degree of its achievement exceeds a certain threshold.

In addition, goals could be presented as quantitative (when the degree of achievement can be defined in specific units of measurement) or qualitative. The main goal in strategic planning should be defined as a linear qualitative goal.

3.2.2. Project Model

A project is a goal associated (when achieved) with implementing specific actions. Such components allow for assessing analytically or expertly the duration of implementation (time) and resources (finances) necessary to achieve the project's goal. These two properties distinguish projects from goals, as projects, unlike goals, are not subject to decomposition.

To increase the adequacy of the model and to rationalize the distribution of available financial resources, the project model considers the dependence of the degree of project implementation on its funding. A piecewise continuous linear function is used, as shown in Figure 1.

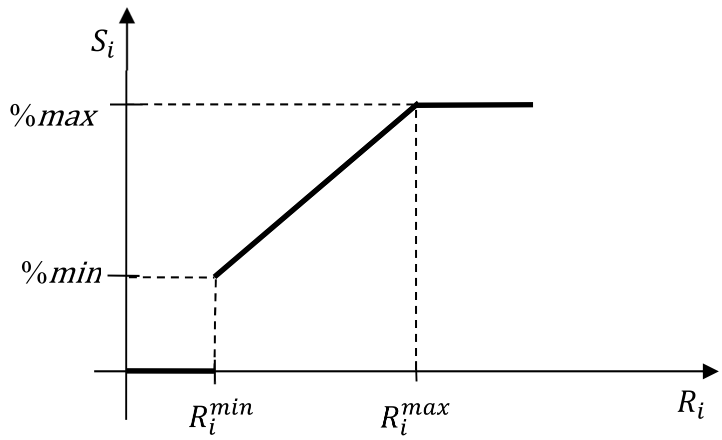

Figure 1: Dependence of the degree of implementation of the i-th project on its funding

In Figure 1, R_i^{max} is the financial resources required to implement the i-th project entirely, and R_i^{min} is the minimum number of resources required to implement the project.

3.2.3. Properties of Influences

Goals, as components of the system, are interconnected: some goals influence others within the model. Influences are established during the decomposition of a goal simultaneously with the formulation of the components of this goal. The components influence the goal, usually called sub-goals, while the goal influenced by the sub-goals is sometimes called the super-goal.

In the goal-oriented graph model, the influences between goals are represented as arcs in the directed graph. If a particular goal directly influences the other, then an arc from the graph's vertex represents the first goal to the second vertex (which represents the goal being influenced).

Influences have several properties. One of the main ones is the relative indicator, the so-called partial coefficient of influence (PCI). PCI is an indicator of sub-goals' direct impact on their super-goal.

It is possible to provide alternative ways to achieve each goal. A set of sub-goals compatible with each other represents each way of achieving the goal. The sub-goals are compatible if the achievement of one sub-goal does not prevent one from achieving another. Such groups of compatible goals are defined during decomposition by providing information on the compatibility of each pair of sub-goals.

PCIs are normalized, and for each *k*-th group of compatible sub-goals:

$$\sum_{j=1}^{K}\left|w_{ij}^{(k)}\right| = 1, \qquad (1)$$

$w_{ij}^{(k)}$ is the PCI of the *j*-th sub-goal of the *i*-th goal in the *k*-th group of compatible sub-goals; K is the number of compatible sub-goals in the *k*-th group.

The modulus (absolute value) is used in (1) because influences could be either positive or negative.

The value of PCI before normalization (1) is defined as the relative contribution of a sub-goal to achieving a specific goal in two ways. Suppose there is reliable information about achieving a sub-goal. In that case, PCI is calculated as a ratio of achieving the sub-goal to the required resources needed to achieve the super-goal, measured in the same units as the effect. If there is no reliable information about the effect of achieving a sub-goal or when the sub-goal is qualitative, expert evaluation methods [2, 4-8], in particular, group expert evaluation methods [9, 10], are used to determine PCI.

Pairwise comparison methods using verbal scales of varying detail are practical and highly reliable, especially when conducting group examinations [11]. It is advisable to apply methods with feedback from experts [12] and with mandatory consideration of their competence in the issue under consideration [2, 13], which allows for achieving a sufficient level of consistency of expert assessments for the legitimacy of their further aggregation [2, 14].

Before applying expert evaluation methods to determine PCI in each group of mutually compatible goals, the formulation of sub-goals with a negative impact is replaced by a formulation with a logical negation.

3.3. Group Decomposition

According to systems thinking, scientific modeling is used to decompose complex problems into less complex ones. It is followed by analyzing these smaller problems and synthesizing a solution to the general problem based on the solutions of partial problems. In the goal-oriented approach, the main goal of the problem, which is a strategic goal, is decomposed.

3.3.1. Decomposition Principles in Modeling

Any modeling involves simplification and neglecting some properties of the modeled object. In the goal-oriented approach, this simplification does not consider insignificant connections between the components of the system. When decomposing a specific goal, only goals that cause a significant impact on the achievement of the decomposed goal are considered.

What influences should be considered significant so that they must be included in a model? The rule is that influences are considered negligible if the relative value of achieving a specific goal does not exceed 10% of the total influence. By following this rule, requirements for the reliability of results will be satisfied. The weights of compared alternatives in a pair must belong to the same order of magnitude [15], and the number of alternatives should not exceed 7±2 [16].

3.3.2. Group Decomposition Technology

Since one person, however qualified, can only endow some of the knowledge, it is advisable to use expert groups when building models.

Group decomposition is a part of a model-building process. It allows a group of people endowed with knowledge to decompose a specific goal and coordinate their ideas on the necessary conditions for its achievement. Knowledge engineers usually decide to perform group decomposition if there is a need for more knowledge on goal achievement conditions.

Knowledge engineers manage the decomposition process. They form an expert group, knowledgeable in the subject domain. Group decomposition consists of the following main stages:

– An expert defines a list of sub-goals. At this stage, each of the involved experts defines a list of goals directly affecting the decomposed goal. This list includes goals (sub-goals) that significantly influence the goal. The expert first analyzes the list of currently available goals. Then they define and add to the list the remaining goals (that cause a significant impact on the decomposing goal). Knowledge engineer terminates this process when a sufficient number of experts have defined their lists of sub-goals.

– Lists of goals are formulated under the knowledge engineer's supervision. This stage is semi-automatic: the knowledge engineer uses Natural Language Processing tools. As a result of this stage, there are lists of goals with identical content combined into groups.

– Group consensus on decomposition. Experts are asked to choose the best wording from each group. The "None" option is added to the list of goals. When selecting the "None" option, the expert chooses not to include a certain sub-goal in the hierarchy. When the expert consensus is reached, the knowledge engineer terminates the process. Then the experts' selections are aggregated. A list of sub-goals with influences on the goal is the result of this stage.

The resulting decomposition is presented as a subgraph of the goals hierarchy graph.

3.4. Structure of the Subject Domain Model

Consecutive decompositions form the subject domain model's structure under a knowledge engineer's supervision. This process begins with the decomposition of the main strategic goal and continues with the decomposition of sub-goals until no goals are left for decomposition. Non-decomposable goals become projects.

When the model is built, the hierarchy of goals is presented to the knowledge engineer as a graph (Figure 2).

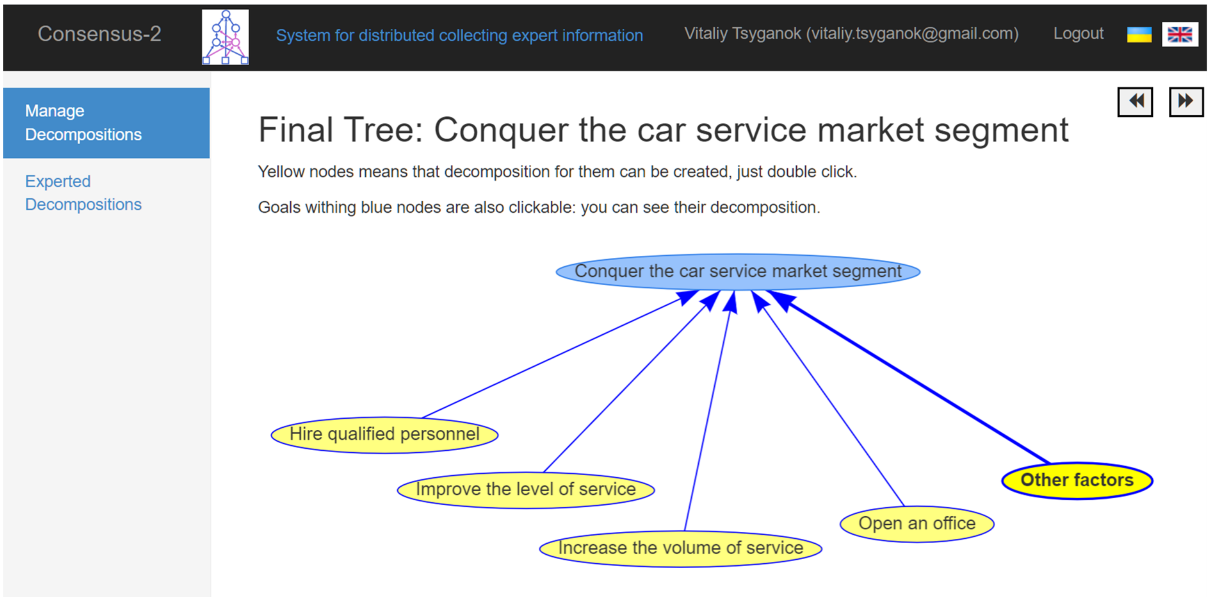

Figure 2: Screenshot of goal hierarchy in "Consensus-2" software

3.5. Model Parameters Selection

After the model structure is built, it is necessary to set its parameters. The knowledge engineer sets some parameters since their values are known. The rest of the parameters are set by an expert group.

The knowledge engineer determines if the goal is quantitative or qualitative, linear or threshold; they also determine the compatibility of sub-goals and whether influences are positive or negative. An expert group determines PCIs and time delays.

"Consensus 2" is a web-oriented software for distributed group expert sessions that implements the technology of group construction of the domain model [17]. When the subject domain model is built, it is possible to solve many problems of decision support, forecasting and analytics. The decision support system "Solon 3" can solve such complex tasks, including constructing strategic plans [18].

4. The Method of Goal Dynamic Evaluation of Alternatives

The Method of Goal Dynamic Evaluation of Alternatives (MGDEA) was developed to evaluate alternative solutions based on a goal-oriented hierarchical model [19]. It was improved to evaluate alternatives in long-term planning [20]. MGDEA is primarily used to evaluate alternative solutions, options, and projects in decision support systems (DSSs). Evaluation is based on the subject domain model made by an expert.

Unlike other methods (for example, multiple criteria methods [21] that use corresponding optimization methods [22]), MGDEA allows the evaluation of heterogeneous projects without a single set of criteria. Moreover, MGDEA does not require an expert to solve the whole problem. It allows a group of experts to contribute to the modeling process. MGDEA can be seen as one of the fundamental methods for expert decision-making support.

MGDEA is a generalized procedure for determining the degree of achievement of a goal in a hierarchy at a given time *t*. When determining the degree of achievement of a specific goal, it is necessary to analyze its sub-goals for each alternative subset of sub-goals compatible with each other [19]. Then $d_i(t)$ (the degree of achievement of the *i*-th goal at time *t*) is defined by the following expression:

$$d_i(t) = \begin{cases} 0, & \text{if} \quad D_i(t) < T_i \\ T_i, & \text{if} \quad D_i(t) = T_i \\ f\big(D_i(t)\big), & \text{if} \quad T_i < D_i(t) < 1 - \sum_j \left|w_{ij}^{(k-)}\right|, \\ 1, & \text{if} \quad 1 - \sum_j \left|w_{ij}^{(k-)}\right| \le D_i(t) \le 1 \end{cases} \tag{3}$$

where $D_i(t) = \sup_k \sum_j w_{ij}^{(k)} d_j(t)$; T_i is the threshold for achieving the *i*-th goal; $f\big(D_i(t)\big)$ is a function of achievement degree of the *i*-th goal at time *t*; $w_{ij}^{(k-)}$ is the PCI of the *j*-th goal in the *k*-th group of compatible goals, which has a negative influence on the *i*-th goal.

Decision variant rating of the *l*-th goal of hierarchy at time *t* is a result of subtracting the main goal's achievement degree $d_0(t)$ when all goals are achieved within the decision variants intended for comparison $d_i(t) = 1,\ i \in L,\ L = \{m..n\}$ from $d_i(t) = 1,\ i \in L\backslash\{l\},\ d_l(t) = 0$. Rating of alternative (decision variant) is the result of subtracting the main goal's achievement degree with the influence of this alternative on the main goal from the main goal's achievement degree without the influence of this alternative.

It was proposed to improve the method to calculate the rating of alternatives to achieve the main goal as well as any chosen goal to expand the possibilities of applying MGDEA.

The process of calculating $d_i(t)$ (the chosen *i*-th goal's achievement degree at time *t*) consists of the following steps. In the hierarchy of goals graph, there is a search for goals that do not affect other goals of this hierarchy — the set of vertices that do not include any arc of the graph. Calculations of goals' achievement degrees start from this set of goals. The initial values of the goals' achievement degree from the set are assigned equal to 1 or 0 (although it is possible to use values from [0,1] interval if a project is incomplete at a given time).

In general, the graph may not have any vertices that do not include any arc. Although this is unlikely and such a case was not considered in [19], the "Other factors" goal should be included in the hierarchy. This goal affects all those goals that could not be achieved by the set available in the hierarchy. If this recommendation is followed, the initial set of goals will not be empty because it will include the "Other factors" goal.

Subsequently, a set of goals is created that can be achieved directly with the goals from the set created in the previous step. All the goals directly influenced by the goals from the previous set are included in the new set. This set may also include goals from the previous set.

The achievement degree at time *t* is determined for each goal of the created set. When determining the goals' achievement degrees, there is a propagation through the hierarchy graph from goals of the lower level to goals of the upper levels and, finally, to the main goal. Suppose the graph has feedback loops (arcs heading from the vertices of higher levels to the vertices of lower levels). In that case, the iterative process that determines the goals' achievement degree is terminated when the modulus of the difference between the calculated values of the selected goal achievement degree during iterations (x) and (x+1) is not greater than the specified accuracy ε:

$$\left|d_i(t)^{(x)} - d_i(t)^{(x+1)}\right| \leq \varepsilon. \quad (4)$$

The specified accuracy ε and planning period are set up as input parameters. Based on the task that is solved with the DSS, the minimum unit of time is one day. By default, the form suggests a recommended planning period. This period is calculated from the hierarchy graph heading from the lower to the upper level (similar to calculating the goals' achievement degrees). The sum of the propagation delays affects the formation of the maximum period duration. Beyond this period, the results of calculating the relative project ratings no longer occur.

MGDEA allows calculating the relative ratings of projects at any time point from the start of their implementation. Since the calculated values of the ratings change only in the so-called reference points of the time axis, these points are proposed to be determined in advance (and not before each iteration). In contrast to the iterative method proposed in [19] for determining the next $t^{(i+1)}$ moment for calculating the goals' achievement degree:

$$t^{(i+1)} = \inf_{k,\ \tau_k \geq t^{(i)}} (\tau_k), k \in \{1, 2, \ldots, n-1\}, \quad (5)$$

τ_k is the value of the delays of the goals' influences in the hierarchy, which contains n goals. It is proposed to move from lower to upper-level goals, calculating all possible delays of the goals' influences in the hierarchy. The process is organized simultaneously with determining the main goals' achievement degree and continues until condition four is met. The list of goals' influence delays is formed together with the calculation of the mentioned recommended planning period, which corresponds to the maximum influence delay.

5. Resource Allocation

At the final stage of building strategic plans, it is essential to determine a list of projects with their financial support, which will make it possible to achieve the strategic goal in a given time interval with known financial limitations for this period. MGDEA allows calculating the main goal's achievement degree at a certain point in time, based on the model of the subject domain, considering the degree of projects' implementation. So, the problem statement is as follows:

1. A set of projects $P = \{P_i\}, i = (\overline{1, n})$.
2. For each project P_i, the dependence function $S_i = f(R_i)$ of the degree of the project's implementation S_i on financing R_i (the function is shown in Fig. 1).
3. The algorithm for calculating the main goal's achievement degree, which corresponds to the vector $\overline{S}$ of degrees of project implementation: $E(\overline{S})$.

Find: vector $\overline{R_x}$, when $E(\overline{S_x}) \rightarrow max$, and $\sum_{i=1}^{n} R_i \leq R_T$, where R_T is the total volume of program funding.

This solution is proposed in [23]. Optimal resource allocation problems are usually solved using various optimization methods, such as mathematical programming, but this problem has specific features:

- When dealing with a weakly structured system model, the goal function cannot be presented analytically; there is only an algorithmic representation (for example, calculating the main goal's achievement degree).
- Since input data for building the model consists of subjective expert assessments (that are not strict and accurate enough), the requirements for the accuracy of resource allocation are

also low. In other words, it is enough to have a non-optimal yet good enough rational version of the solution.

From the practical point of view, it is advisable to move to a discrete domain from a continuous scale. For this purpose, it is proposed to specify the resource allocation accuracy as input data. It represents a discretization unit of the financial resource.

Evolutionary algorithms (a subset of evolutionary computations) are essentially variants of targeted random search. Therefore, evolutionary algorithms can solve problems with mentioned features.

It is proposed to use a genetic algorithm (GA) modification, first proposed by Holland [24]. GA belongs to the larger class of evolutionary algorithms. It is an algorithm that is used to find a solution to complex problems by sequentially selecting and combining the desired parameters using mechanisms that are based on biological evolution.

GA uses a set of individuals (population), which are basically strings, and each of that strings encodes one of the solutions. Therefore, GA differs from most optimization algorithms, which can only operate with one solution variant at a specific time. Among all individuals in the population, the following are selected using the fitness function:

- Fitter solutions (solutions that have the maximum fitness function values) that can generate new offspring.
- Bad solutions (with low fitness) are removed.

Thus, the adaptability of the new generation is, on average, higher than the previous one.

One of GA's main advantages is its versatility. Fitness function and solutions' coding are the only parameters that depend on a specific problem (other steps are performed similarly). Therefore, these parameters should be the main focus of the resource allocation problem.

The function of the main goal's achievement degree at given levels of project implementation is used as a fitness function. This function has already been implemented and used in many DSSs, so there is no need to reinvent it. It can be used as a fitness function of the GA.

The resource specified for further distribution between projects is subject to discretization (division into elementary (indivisible) parts). The possible solution to this problem is a vector with the number of elementary parts of the resource allocated to a specific project as the vector's elements.

It is necessary to pre-calculate the implementation degree of each project with the specified funding to calculate the fitness of individuals (the main goal's achievement degree). Therefore, finding the project implementation degree corresponding to the decision vector element is necessary. Funding parameters for each project are pre-entered by business plan authors.

It is vital to choose the GA's operators correctly. The following GA operators were used for this implementation: tournament selection with a set of two individuals, one-point crossover, mutation, and elitism.

It is proposed to use the following experimentally chosen input parameters by default:

- 50 individuals in the population,
- 0.05 mutation probability,
- 50 generations with the same result as a stop criterion.

It is possible to change these parameters by selecting more suitable ones to obtain a result for a given model effectively.

So, in this research, the problem of rational distribution of limited resources between projects was solved. The work results were confirmed with the correct parameters' settings and matched with the brute force search results. Verification was performed using samples with a limited number of projects and a small number of given elementary units out of the total amount of resources.

6. Conclusions

Theoretical foundations and methods were proposed for the reliable acquisition and use of collective knowledge in different areas, which made it possible to develop the knowledge transfer platform toolkit for strategic planning in various domains.

The strategy, in this context, is a list of selected measures to achieve the system's main goal in a specified time using limited resources.

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