Solving interdisciplinary tasks: the challenge and the ways to surmount it

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Abstract. The paper outlines the first steps on the path to identification and systematization of the types of purposeful activity tasks and to the ways to solve them. The authors have been developing a non-traditional interdisciplinary approach and apply it here to the concept of a task as such. This research area shows a good promise, since it enables the development of a framework for a holistic objective interdisciplinary picture of knowledge in any scientific field. The result of the work is the classification of object types and their characteristics, as well as the classification of the latter in the aspect of their relationship to objective reality. This result points out key directions to the systematization of objects, their related task types, and solution methods.

1. Introduction

The increasing relevance of solving interdisciplinary tasks reflects the need to return to a holistic perception of the surrounding world. This perception was partially lost in the period of rapid differentiation of the areas of knowledge and the corresponding narrow specialization. These processes resulted in different development level of various areas. To overcome the challenge, a return to the integrity paradigm is required, because the research experience shows that breakthrough solutions can be found, as a rule, either with substantial use of the results of more developed areas of knowledge or at the junction of different areas.

When solving interdisciplinary tasks at the junctions of areas, it is necessary to agree on the concepts related to different areas of knowledge, whereas employing solutions from another area requires the appropriate formulation of the problem in terms of the area of interest. This implies the following difficulties: coordination of concepts and terminology from different areas, development of a unified view of apparently cardinal difference in solution methods traditionally inherent in different disciplines.

The difficulties mentioned are increasing by the occurring polysemy of a number of concepts in use (even within the same area) can be also referred to as an obstacle in eliminating the separation.

For example, “parameter” according to [1] is a quantity whose values distinguish the elements of a certain set from one another. The same concept, according to [2], means “generally, any characteristic that can help in defining or classifying a particular system (such as an event, project, object, situation, etc.). That is, a parameter is an element of a system that is useful, or critical, when identifying a system or evaluating its performance, status, condition, etc.”. According to the first definition, parameter and value are synonyms because, on the one hand, a parameter is a type of value, and, on the other hand, because a value (as well as a parameter) is by definition a quantitative means of distinguishing private
realizations of a value. According to the second definition, the parameter is identical to the attribute used in both qualitative and quantitative identification of a system.

The purpose of this work is to present a path which, according to the authors, will allow to overcome these challenges.

2. Possible ways to overcome the challenges of solving interdisciplinary tasks
An obvious way to overcome these challenges is a joint discussion and mutual understanding of experts in problematic areas resulting in the development of mutually acceptable solutions. A key drawback of this approach is the participation in the discussion of experts from a limited number of areas that certainly limits the scope of the solutions developed.

Another way is to rely on a holistic world view covering all possible areas of conscious activity and the tasks solved in them. By looking “from above”, this approach potentially allows to identify and systematize the tasks and methods for solving them by the levels of their interdisciplinary community, starting from their place of origin, clearly separate interdisciplinary points, (i.e. the points common to different areas) from the ones that inherent in a particular knowledge area(s). On this way, it becomes extremely important to ensure the unambiguity of the interpretation of certain concepts. This interpretation should be achieved by a generally accepted logical conclusion rather than just by mutual agreement.

The existence and effectiveness of the second path is indicated by the interdisciplinary nature of information technologies and the underlying mathematical methods.

The research aimed at developing constructive tools for implementing the second way was initiated at the Institute of Control Sciences of Russian Academy of Sciences. These studies were based on the ideas expressed by V. Kneller in a number of works [3-7], the developed inductive-deductive interdisciplinary approach to revealing and systematizing methods for solving tasks of purposeful activity (hereinafter, the Approach) and the experience of its application to a number of key tasks, such as creating a conversion of physical quantities [8], ensuring the invariance of the transformation to the influence of disturbing factors [9, 10], analog-to-digital conversion [11]. The mentioned approach involves the following steps: (a) identify the essence and formulate the task in terms of unambiguously interpreted concepts, (b) generic generalization – repeated transition to a more general task, all solutions of which are potentially applicable to solving a generalized task, (c) consider the procedure for solving the problem at the highest level of generalization from various aspects in order to identify possible methods of solution, d) the top-down movement to the initial task – the transfer of solutions of a more general task to the level of less common tasks allowing for the specificity of the latter.

The authors propose to apply the Approach to the task as such: to reveal the deep sources of its origin and to trace the possibilities caused by these sources. The results obtained would be obviously applicable to any areas of knowledge and, just by the way of their construction, form an interdisciplinary communication language.

3. Fundamentals of the way to systematization of tasks and their solution methods based on the Approach
The result of executing a sequence of steps prescribed by the Approach makes it possible to identify and systematize the types of tasks arising from the constructed picture by operating only with extremely general attributes of the task as such. By virtue of the logic of the Approach, it is necessary to identify and systematize consistently the solution methods common to any tasks as well as methods that are unique to each of the tasks at the highest level of generalization. Next, it is necessary to investigate possible directions of specifying the attributes inherent in the task, as such, and its types at the highest level of generalization for problems. This specification engenders subsequent levels of the hierarchy of types of tasks and their inherent solution methods, forming a holistic picture of both the tasks solved in the process of human activity and the methods for their solution.
The main distinctive feature of the direction under consideration is the urgent need in introducing unambiguously interpreted generally accepted concepts and in harmonizing them with the concepts adopted in various scientific fields and schools.

The encouraging results were obtained at a number of stages of the presented path, some of which were presented at the XIII All-Russian Conference on Control Problems “RCCP-19” and will be briefly described below; other works are either in the process of research or are waiting for their enthusiasts. It is extremely important that the tasks solved at the same time be precisely positioned in the overall picture of the tasks and methods for their solution, which may require certain improvements of the above-mentioned holistic picture based on the results of these studies.

To apply the Approach in a new area, it is, first of all, necessary to provide an unambiguous definition of the task, as such, through extremely generalized concepts. A task is a formulated by the subject(s), conscious and sensible necessity to satisfy the need for something under certain conditions. Consistently generalizing the detailed attributes of comprehension, consciousness, and activity, we come to philosophical concepts of the special, the single and the Universal. But since it is known from the practice that the Universal is capable of development, it is necessary to indicate the reasons for such development. From the authors’ viewpoint, this is the energetic fullness of the Universal and the possibility of changes in the manifestations of this fullness.

4. Key directions of task types specification
Since the concept of a task and the concepts involved in defining a task, such as need, formulations, conditions, etc., are singles, the specification of task types is entirely determined by the specification of the types of single ones. In turn, the species of the single are determined by the development of the Universal, starting from the single, as such.

The research [12] allowed to build a hierarchical picture of singles species up to the level of conscious comprehension activity, whose distinctive feature is the presence of tasks and methods for their solution. This picture in a simplified form, conditionally divided into layers, is shown in figure 1. The layers in the figure are separated by horizontal lines; attributes of layer separation are indicated on the right side. In the Figure 1 OS is the operating (active) single. In accordance with the picture construction procedure, the terms used in Figure 1 were selected as the best (from the authors’ viewpoint) fits for the content of the revealed concept, rather than as a result of the generalization of various concepts denoted by one term. For example, the term “recognition” in figure 1 means establishing or denying the fact that a single belongs to a certain set, the term “detection” means establishing the fact of the presence or absence of a single, the term “identification” means the collation of singles in order to establish or disprove their similarity.

The highest layer is the layer of the only single. The next layer focuses on a set of singles. This is followed by a layer that takes into account the possibility of connections between the singles, then a layer, which is characterized by the possibility of singles variability and, finally, a layer where additional possibilities open up associated with operating (active) singles, which may have the potential for consciousness and comprehension.

We would emphasize once again that the decomposition shown in figure 1 is extremely simplified; theoretically, a more detailed one can be proposed. The borders of these layers are blurred in reality. But in our case, the nature of the division into layers is not that important: the main thing is to illustrate the existence of a consistent logically based procedure for identifying and systematizing the types of objects, based on the possibilities that are consistently opened in the process of the development of the Universal.

Further specification directions also generate the types of single but already detailed objects, presented in figure 1. First of all, this detailing of objects appears through the need to describe the features of specific singles ones through their inherent characteristics. Since characteristics are the product of comprehension activity, they cannot be considered without employing the concept of subject.
By analyzing the characteristics in more detail, it is easy to see that they can also be systematized according to the generic principle, forming their own hierarchy. We propose to designate the characteristics corresponding to these levels as attributes, indicators, values, and constants. Selected terms are recommended; it is their semantic content that actually matters.

Here, attributes are the most common, qualitative characteristics irreducible to each other. Indicators are also qualitative characteristics, but they depend on attributes or other indicators. A value is a property that is common in a qualitative sense for a certain set of homogeneous (by the totality of attributes and indicators) singles, and in a quantitative (estimated, orderable) relation, single for each

**Figure 1.** The hierarchy of key classes of objects at the highest level of consideration
element of this set. Values are divided into intensive (estimated) and extensive, for which the axioms of addition are valid. And, finally, a constant is a characteristic permanent in its quantitative content.

The above hierarchy allows to define a complex object as an object with several independent (i.e., not reducible to each other) characteristics at the same hierarchy level. From this viewpoint, multidimensionality is a type of complexity that involves the presence of several independent scalar values characterizing a complex object.

Next direction of the origination of task types is the nature of the characteristics. From this viewpoint, the characteristics are divided into real (objectively existing) and phantom (purely subjective, unrelated to reality). The first, in turn, are subdivided into two classes. The characteristics of the first class are objective in their essence, the others are subjective, but, at the same time, they reflect the properties of real objects as well as the laws and regularities applicable to them. We conditionally designate them as physical and nonphysical, meaning in this case their attitude towards objective reality rather than their membership in a specific field of knowledge. Physical characteristics reflect directly the nature of things (e.g., resistance, valence), whereas non-physical ones are auxiliary and reflect the characteristics of real objects only indirectly (e.g., reliability, appearance and characteristics of a real object model). The description of objects through their characteristics within the framework of a task has a model nature which reflects the most significant characteristics of the objects from the viewpoint of the task under consideration. Thereby, variable quantitative characteristics of such descriptions not necessarily tied to their nature will be referred to as parameters.

The multiplicity of task types is determined not only by these directions, but also by their conjunctions, possible consistent combinations of tasks of different types, as well as by transitions to tasks with combined objects or the result of their interpenetration.

5. Development outlook and future work

Consideration of the variety of tasks that are logically derived from the picture briefly presented in this paper on the one hand, and the variety of practical tasks on the other, results in the need to establish a correspondence between these varieties. This requires the development of an extremely formalized procedure for determining the place of each real-life task in the overall picture and, at the same time, determining the sources of the origin of this task and the component tasks from which the initially considered task was formed. It is quite obvious that the availability of knowledge about the methods for solving the above mentioned component tasks and the rules for combining them opens up the way to considering potentially possible (in addition to the invented) methods for solving the original task. This proves the practical significance of the direction being developed.

From a theoretical viewpoint, it is critically important to identify the sources of origin of various key tasks, such as, for example, creating a transformation, ensuring the transformation invariance to the influence of interfering factors, measurement, monitoring, prediction, and diagnostics tasks. Answers to relevant questions will allow to specify unambiguously interpreted definitions of relevant concepts. The traditional way of defining such concepts, based on accumulated experience, due to its multidimensionality often leads to a number of definitions sometimes conflicting with each other.

To illustrate some opportunities opened up by the Approach, we consider a part of a logical chain arising from the need to organize the solution of a task regardless of its type. The solution of the task under complete or partial uncertainty of object’s characteristics preventing the attainment of the desired result causes the need for developing control actions aimed at overcoming the specified obstacle. Under these conditions, it is required, first of all, to establish the fact of the need to perform control actions. This necessitates (i) the detection of monitored characteristics, which make it possible to indicate the necessity of the mentioned actions and to check the conformity of these characteristics to the norm, i.e., a state in which no control action is required. The statement of the need for impacts, in turn, raises the need (ii) for identifying events which cause the appearance of a nonconformity and which should be affected in order to eliminate the nonconformity. And, finally, there is a need (iii) to determine the characteristics of impacts (points of application and, if these characteristics are values, the intensity of impacts). By convention, we denote the selected needs, respectively, as needs in monitoring, diagnosing
and determining control actions. If we take into account the aspect of localization of the state of characteristics in the process of object changes, then each of the monitoring (in relation to controlled characteristics) and the diagnostics (in terms of conditioning characteristics) tasks is detailed in three subtasks: per the current state, per the previous one, and per the state resulting from the current one.

It can be noted that the known definitions of diagnostics (see, for example, [13–15]) do not contradict the need for detecting events that cause the appearance of a discrepancy; this need is detected by logical inference rather than by generalizing various formulations of diagnostics.

Thus, following the Approach allows not only to establish the places of certain tasks in the overall picture, but also to specify their wording in the most accurate, unambiguous way due to the principle of establishing the independence of tasks once their solution methods are independent.

Given the exceptional practical significance of operating procedures with extensive characteristics, one of most important tasks also should be recognized as the task of establishing a relationship between quality and intensive characteristics on the one hand and extensive characteristics on the other. For physical extensive quantities, this task is reduced to the classical measurement task based on exemplary measures. Otherwise, we are talking about a generalized theory of measurement, which includes using the significance scores given by experts or as a result of testing procedures. These scores are accepted as the values of the corresponding extensive characteristics. The corresponding field of knowledge is discussed, in particular, in the works by L. Finkelstein (e.g., [16]).

At the same time, it is known [11] that a measurement task (even in its generalized version) requires solving a number of simpler tasks: dividing the set of singles into subsets, designating subsets (forming a scale), localizing the single to be measured on this scale, and designating the result localization.

The results of the application of the Approach indicate the existence of a small set of fundamental types of tasks arising at the highest level of generalization. It is these tasks that underlie all possible types of tasks, and the methods for their solution determine the methods for solving possible tasks. Their revealing and systematization is an important component of the theory of tasks requiring further research.

6. Conclusions
The material presented in this study corresponds to initial stages of building an interdisciplinary theory focused on identifying and systematizing the types of tasks of purposeful activity and methods for solving them, as well as formalizing the synthesis of methods for solving various tasks.

The study results outline possible directions of specifying the tasks of purposeful activity, and, hence, the methods of their solution, regardless of the related knowledge area.

Built general overview of the types of objects and, tasks underlie not only the development of a generally acceptable conceptual and terminological toolkit, but also the establishment of interdisciplinary bridges in the synthesis of highly efficient solutions at the junctions of various fields, as well as innovations in the learning processes of relevant disciplines, starting at the interdisciplinary level.

The material of this study claims to be new mainly in terms of the comprehension of logical connections arising from the types of objects, their characteristics and levels of generalization and, therefore, determining the species diversity of tasks and methods for their solution.

The authors hope that the study will stimulate discussion and further research aimed at harmonizing within the framework of a single whole multiple substantive views in various fields of knowledge.

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