Building an ontology for system analysis

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Abstract. System analysis as scientific and engineering discipline underpins research and development in other areas. However, system analysis models and methods are often taught separately and, as a result, system analyst cannot form a holistic understanding of this area. In order to deepen our understanding of system analysis' concepts and relations the ontology of this area was built. It was constructed based on models and methods of system analysis considered as knowledge patterns. The concept of system was selected as a central concept of ontology. Other important concepts, such as goal, function, decision and process are relating to it. Finally, the applications of created system analysis ontology for teaching system analysis in high school and as a part of semantic grid are discussed.

Keywords: system analysis, ontology, pattern, model, concept, semantic grid..

INTRODUCTION

System analysis (SA) is a methodology, which treats complex objects as systems with goals. It explores the properties of such systems and their dependencies as relationships between goals and means to achieve them.. The prominent feature of system analysis is the synthesis within a common methodology of related methods, tasks and techniques that were previously used separately to solve partial problems. System analysis includes the general principles, models and methods used for research and decision making in multiple subject areas. The mainstay principle of system analysis requires to consider the system holistically, not just as a mere sum of its parts. This emphasizes the importance of research on relationships and dependencies in a system. Other principles stress the importance of goals, and being efficient in attaining them [1].

The reform of Higher Education system in Ukraine implies, among other, the presentation of knowledge and skills of future graduates as sets of competences [2]. The Higher Education standard for the field of system analysis requires from graduates to be able to apply the methods of system analysis in practice with the aim to create and research the models for processes and objects [3] in various subject areas. This competence implies the system analytics' skill to identify and use typical models and methods of system analysis to resolve problems from different domains. The precondition for such skill is the deep understanding of system analysis subject, its concepts and dependencies between them.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

The task of identifying and applying typical system analysis models and methods requires detecting of specific structural patterns in a system, identifying their correspondence to SA models, acquiring relevant data, applying system analysis methods and correctly interpreting and using their results.

The principle of identification and reuse of typical patterns was pioneered in software architectures development [4] where it allows to substantially streamlining the process by using standardized and proven solutions. There is also an ongoing research in the area of typical conceptual patterns identification for task analysis and design of complex information systems [5,6]. The authors of article [7] have developed an ontology for service-oriented systems, which includes on its top-level several foundational SA concepts (system, subsystem, environment, input, output, and efficiency criteria). However, while this work could be considered as a successful application of SA principles to the specific area of ontological modelling of service-oriented systems, it does not provide in-depth insight into concepts and relationships in SA area itself, which is necessary for application of SA methods across multiple domains.

Moreover, the analysis and formalization of foundational system analysis patterns is still lacking. On the other hand, detected patterns are often considered separately, without explicitly tracking dependencies between them. As a result, system analytic cannot understand a whole picture of a subject area, he does not know problems which can be solved and typical solutions, which impairs his ability to make sound and effective decisions.

In order to form a holistic understanding of system analysis subject area it is advisable to use the ontological approach, resulting in creation of formalized conceptual model of subject area represented as tuple

$$On = (C, R, A) \quad (1)$$

where *On* is an ontology, *C* – the set of concepts, *R* – the set of relations and *A* is a set of axioms and constraints defined for concepts and relations from *C* and *R* [8]. The construction and use of ontology for any subject area not only provides standardized dictionary of terms and explains their relationships, but also allows to weed out ambiguities and contradictions. Ontology modelling tools such as Protégé, support logical reasoning and implement rules and query engines via plugins [9].

The development of methodologies for ontology construction is still an ongoing research endeavor. For example, in [10] a new methodology for ontology development based on facet analysis and analytico-synthetic classification approach is proposed. However, the authors of [11] note that most methodologies lack sufficient detail level and currently there is no mature methodology for ontology construction. When comparing such methodologies authors often focus on analysing the process of ontology development. In [12] the process of ontology construction is specified and several methodologies are evaluated on the basis of conformance to this process. Authors [12] conclude that the lack of ontology development standards and guidelines is an impediment to obtaining high quality ontologies.

THE SELECTION OF SOURCE DATA FOR ONTOLOGY CONSTRUCTION

An important factor in ontology construction process is selecting a right source which is often omitted in current research. This selection largely depends on subject area and purpose (competence) of ontology. Different sources are used for ontology construction. Thus, in [13] an ontology is built in process of analyzing texts from selected subject area. In [14] the ontology of mobile systems takes into consideration the location of object, which helps to make decision in the context of location. In the work [15] technical standards were selected as a source of ontology, because they provide a coordinated and curated dictionary of technical terms and their definitions. In [16] an ontology is built as a result of business tasks analysis in context of business process. The standard IDEF5 for creation of ontology uses assertions about objects, their properties and relationships in chosen subject area [17]. Terminology dictionaries are good source for concepts. However, they do not contain information about relationships and constraints in subject area. As a general rule corpus of knowledge used for ontology construction should: a) contain knowledge about subject area in sufficient amount and detail; b) take into consideration the competence of ontology, which impose further restrictions on ontology content; c) simplify and streamline the ontology creation process. Thus, all ambiguities, contradictions and errors should be removed from knowledge corpus prior to building of ontology.

Correctly selected knowledge source for ontology construction contributes to such quality characteristics of ontology as completeness, consistency, conciseness, non-redundancy and expandability [18].

In case of system analysis subject area we selected as a corpus of knowledge the set of conceptual models used in this area. A conceptual model defines concepts, relations and constraints, which should be integrated in the common ontology. On the other hand, the detection of conceptual model pattern is a necessary condition of using system analysis methods when solving problems in practice. The set of conceptual models reflects the whole system analysis' subject area, and is linked directly to corresponding methods and procedures.

A conceptual model Mdi is formalized as a tuple, containing model ontology Oni and reference to corresponding method or procedure Ac_i:

$$Md_i = (On_i, Ac_i) \qquad (2)$$

Ac_i refers to method needed to apply the specific model. Model ontology contains only concepts, relations and axioms appearing in the model, enabling for system analyst to focus at task at hand. The information about models and methods should be preserved as a part of common ontology On. This will allow to find models and methods using the specific concept or relation and analyze models in context of concepts and relations. Additionally, this will allow in process of system research to move from one model to another, exploring their dependencies.

Let's define a set of n models:

$$Md = \{Md_i | i = 1 \div n\} \qquad (3)$$

Than a common ontology is constructed as a union of task ontologies and model/method ontologies:

$$On = \bigcup_{i-1}^{n} On_i \bigcup_{i-1}^{n} Ac_i \qquad (4)$$

BUILDING SYSTEM ANALYSIS ONTOLOGY BASED ON ITS CONCEPTUAL MODELS

In the process of system analysis ontology construction we used conceptual models shown in table 1 below.

The selection of models for analysis was done according to such reasoning. Firstly, we included the core system analysis models which define central concepts and relations for this area. Those are the "System and environment", "System and subsystems", "System and goal", "System and functions", "System and use-cases" models. Thus, "System and environment" model separates system from environment and states that they influence each other. "System and subsystems" model postulates, that system can be decomposed into subsystems and system's functionality can be obtained as a result of those subsystems interaction. "System and goal" model states that system analysis studies goal-oriented systems. "System and functions" models suggests which capabilities should be implemented in a system. "System and use-cases" describes the system from user perspective. The models of the first group describe the core concepts, directly linked to central (System) concept.

Secondly, we added to the list the models which further describe the core concepts of Goal, Function and Use-case. For example, for a Goal concept the "Goal completion" model defines the condition allowing to check whether the goal was attained. "Goal and efficiency model" states, that for each goal the efficiency criteria should be specified. "Goal tree" model allows to decompose the root goal into subgoals. IDEF0 model describes concepts and relations used in function specification according to requirements of IDEF0 standard. "Process and task" model specifies how the specific use-case will be implemented.

Table 1. Conceptual models of system analysis

#	Model	Concepts	Relations	Axioms
1	System and environment	System, environment	influences	
2	System and subsystems	System, subsystem	includes, is Part	Subsystems implement system functionality
3	System and goal	System, goal	has, gives meaning	
4	System and functions	System, function	implements, implenented by	
5	System and use-cases	System, use-case, actor	is described, performs	The set of use-cases implements functions
6	Goal completion	Goal, completion condition	defines completion, completion defined by	
7	Goal and efficiency	Goal, efficiency , criterion	evaluates, defined by, how efficiency is attained	
8	Goal tree	Goal, subgoal	implies attaining, is necessary	In order to attain a goal, all subgoals must be attained
9	IDEF0	Function	is input, is output, is control, is mechanism	Relations link functions
10	Process and tasks	Use-case, process, task	use case implemented, contains	
11	Decision making	Task, problem, expert, decision	appears in, analyze problem, make decision.	Problem appears when task is performed
12	Analytical hierarchy	Goal, criterion, alternative	evaluates importance, is chosen according to	

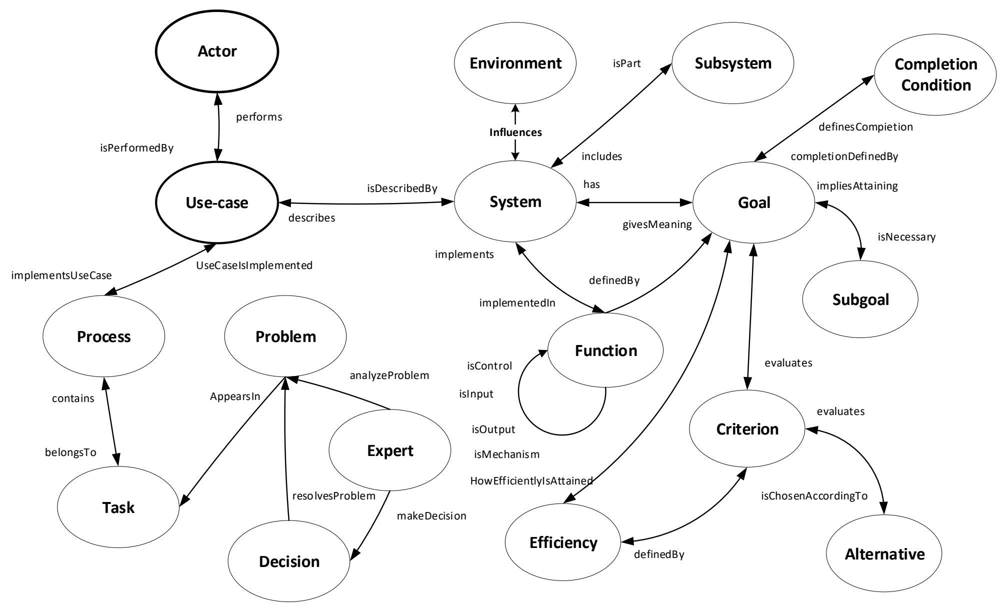

Fig. 1. The fragment from system analysis ontology

The third group of models represents situations and methods from system analysis toolkit with their relations to core system analysis concepts. This group of models is represented by “Decision making” and “Analytical hierarchy method” models. The list of conceptual models is by no means complete and can be extended with other models.

The fragment of constructed ontology for system analysis is presented on fig. 1 in the form of semantic network.

CONCLUSION AND DISCUSSION

The system analysis ontology created on a basis of conceptual models creates a holistic picture of system analysis area and allows to explicitly represent dependencies between its concepts, relations, models and methods. Such representation forms a basis for reasoning, revealing patterns and applying system analysis methods in various application areas. Contrarily to approach from [7] where system analysis concepts are parts of domain ontology, we consider system analysis ontology as a general ontology, which can be integrated in different domain ontologies, for example, according to guidelines, presented in [19].

Thus, this ontology can be helpful for detecting system analysis patterns in educational environment while building curricula and forming individual learning trajectories for students in disciplines heavily relying in system analysis methodology.

For example, the review of curriculum for “System analysis” curriculum reveals the foundational role of system analysis for a large number of disciplines such as information technologies, operations research, decision support, project management, business analysis, strategic analysis and management (fig.2).

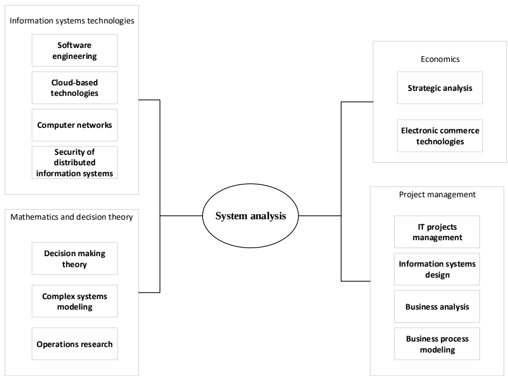

Fig. 2. The result of the processing of images with a color change

Moreover, the ontology of system analysis can be used in semantic information systems such as semantic e-science grid to represent, store and apply knowledge about system analysis principles and patterns [20].

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