TRIZ Developers Summit 2019
June 13-15, 2019. Minsk, Belarus

TOWARDS ONTOLOGY OF TRIZ

Andrew Kuryan[a], Valeri Souchkov[b], Dmitry Kucharavy[c]

[a]*EPAM Systems, Minsk, 220141, Belarus*

[b]*ICG Training and Consulting, Enschede, 7511KH, The Netherlands*

[c]*See Core Project, Strasbourg, 67000, France*

Abstract

Today, the development and transformation of TRIZ continues in the following directions:

1. Emergence of new TRIZ tools and refinement of the existing TRIZ concepts. 2) Integration of TRIZ with other knowledge domains (e.g. Design Thinking, Product Development, Lean Production, Product Management, Business System Engineering). In the course of such integration, the necessity arises to match the concepts and models of TRIZ against concepts that belong to the other domains. 3) Development of systems of TRIZ Education and evaluation of knowledge and skills of TRIZ.

Due to their limited contents, dictionaries and glossaries of TRIZ terms available do not help much with the development of TRIZ along abovementioned directions. Can an ontology of TRIZ eliminate the deficiency of the dictionaries and glossaries to enhance further development of TRIZ through establishing relations between TRIZ concepts and models?

The paper presents an approach targeted at developing, applying and maintaining the ontology of TRIZ.

Keywords: TRIZ, domain knowledge, dictionary, ontology

Аннотация

Сегодня развитие (трансформация) ТРИЗ идет по нескольким направлениям:

1) появляются новые инструменты ТРИЗ и происходит уточнение существующих понятий ТРИЗ; 2) ТРИЗ интегрируется с другими областями знаний (например, Design Thinking, Product Development, Lean Production, Product Management, Business System Engineering др.). В ходе такой интеграции возникает необходимость согласования понятий и моделей ТРИЗ и понятий из других областей знаний. 3) Развиваются системы ТРИЗ образования и системы оценки знаний и навыков ТРИЗ.

Словари понятий ТРИЗ не позволяют удовлетворить развитие ТРИЗ по перечисленным направлениям. Может ли Онтология ТРИЗ устранить данный недостаток словарей и удовлетворить требования развития ТРИЗ через установление связей между понятиями и моделями?

В статье авторы представляют подход, который позволит создать, применять и поддерживать Онтологию ТРИЗ.

Ключевые слова*: ТРИЗ, область знаний, словарь, онтология.*

1. Why Ontology?

1.1. Solving a problem of knowledge structuring

In recent years, we have been observing immense growth of volume of knowledge and information in many different knowledge domains, primarily, in those which experience intensive research and development. Such research leads to finding new links between the existing concepts which are already described in the domain as well as discovering and introducing new concepts to the domain vocabulary. However, sometimes relationships and meanings of new terms often remain implicit and stay invisible to those who must deal with domain knowledge for different purposes: to perform new research or new developments, to teach, and so forth. It may lead to confusion when using and re-using knowledge and concepts described in a certain domain.

While one can use dictionaries, glossaries and textbooks available in a knowledge domain which explain meanings of the terms, links and relationships between different terms may remain unclear. On top of that, some concepts and terms which did not go through careful verification might even contradict each other.

TRIZ is a knowledge domain which has been gradually expanding since its inception in the middle of the 1950s. The TRIZ domain includes three categories of terms. First, TRIZ introduces its own unique specific terms which are not present in other domains and are used within the context of TRIZ only (e.g. "*administrative contradiction*", "*ideal final result*", etc.). Second, TRIZ uses terms from other knowledge domains, such as innovation, physics, philosophy (e.g. "*physical effect*", "*invention*", "*contradiction*", etc.), and so forth. In this second part of TRIZ domain terminology, meaning of some terms can be rather specific and do not fully match their general meaning in other domains. It happens, for example, with the term "*function*" has its own meaning. In TRIZ, meaning of the term "*function*" does not match the meaning of function in mathematics or Systems Engineering. In the third category of terms, their meaning fully matches meaning of the same terms in other domains. On the other hand, recent changes related to refinement of these terms in native domains are not always followed by TRIZ researchers.

The latest version of the Glossary of TRIZ and TRIZ [1] related terms includes over 360 terms from all three categories. It is often a case when the same term is often used in different parts of TRIZ body of knowledge. It was found that using the Glossary of TRIZ and TRIZ related terms only to clearly understand meanings and relations of the TRIZ terms is often not enough. A deeper approach is needed, with a focus on establishing and presenting relations between the terms.

A *domain ontology* was suggested as a solution to properly organize and structure knowledge within a specific domain [2]. Rather than just explaining meanings of domain concepts through description of different terms and their definitions as it is done, for example, in glossaries, ontologies introduce semantic relations between these terms which indicate how a certain concept relates to other concepts in the domain. For example, the terms "*land vehicle*" and "*sea vehicle*" may relate to each other through establishing their relation to the parent term "*transportation means*".

An ontology defines a common vocabulary for researchers who need to share information in a domain. It includes formal definitions of basic concepts in the domain and relations among them. According to Oxford Living Dictionary of English, "*Ontology is defined as a set of concepts and categories in a subject area or domain that shows their properties and the* *relations between them*. [3]. Where concept is defined as *perceived regularities in events or objects, or records of events or objects, designated by a label*. [13]

There are different ways to establish and present relations between domain concepts: taxonomies, semantic networks, graphs, and so forth. Often, domain ontologies involve different types of relations, both vertical and horizontal.

Summarizing, among the main reasons of developing a domain ontology are the following [4]:

- To share common understanding of the structure of information.
- To enable reuse of domain knowledge.
- To make domain assumptions explicit.
- To separate domain knowledge from the operational knowledge.
- To analyze domain knowledge.

1.2. Ontologies and TRIZ

The first attempt to apply the ontological approach to formalize and structure knowledge of TRIZ and integrate it at high level with knowledge of physics, and knowledge of innovative engineering design was done during developing the ontology INDES [5]. The framework proposed a way to describe different types of relations between the concepts of tree different domains.

Similar research but focused on a narrower area of TRIZ domain knowledge was done to build an ontology which links physical effects, Substance-Field Models and Inventive Standards [6], [7]. This research went further to formalize the ontological concepts with the support of existing ontology development software tools. The inventive standards ontology and the physical effects ontology were built in OWL (Ontology Web Language) - an ontology language for semantic web, and the constraint knowledge of using physical effects is formalized in SWRL (Semantic Web Rule Language). However, the way the information presented in this research relates to description of the domain rather than to ontology.

Another type of TRIZ ontology is presented in [8]. In this approach, TRIZ is considered as a part of “meta-ontology” which is a high-level, domain-independent ontology, which is used to define the meta-domain with “meta-concepts”: common concepts of all domains involved. It provides a framework from which more domain-specific ontologies may be derived.

1.3. Research goals

All the ontologies listed above targeted at integration to software tools that would incorporate knowledge of TRIZ to be processed by (semi-) automated reasoning engines. But it is obvious that a simpler, human-oriented version of TRIZ ontology is also needed to meet two types of goals:

1) With respect to the existing TRIZ Glossary:
    - verify validity of each term in the existing TRIZ Glossary;
    - refine terms and definitions in the existing TRIZ Glossary;
    - discover and bridge gaps in the existing TRIZ Glossary.

2) With respect to TRIZ in general:
    - improve quality of learning and understanding TRIZ;

- help to avoid misuse and wrong interpretation of TRIZ terms;
- avoid introduction of new terms without necessity;
- discover inconsistencies in using the TRIZ terms;
- facilitate development of a theory which can provide quantitative predictive power;
- help integrating TRIZ with or within other domains.

Contrary to the ontologies mentioned above which selected TRIZ concepts from scratch, the existing TRIZ Glossary of TRIZ and TRIZ-related terms was chosen as a basis for building the new ontology.

2. Approach

2.1. Brief description of methodology for study

At first, two documents presenting TRIZ terms were considered: Glossary of TRIZ and TRIZ related terms, Version 1.2 by The International TRIZ association – MATRIZ [1] and OTSM-TRIZ Glossary, Working version [9]. To define a scope of research, it was decided to take the version of Glossary presented in [1] as a starting point. The texts from the Glossary were imported into spreadsheet format for ease of use. In order to improve consistency of the future ontology, the authors filtered the selected data for terms from classical TRIZ as defined in [10].

After preliminary study, the source of data included 249 original terms and 29 synonyms relevant to classical TRIZ. In order to verify consistency of the study, one more source of data was examined [11]. The analysis did not identify any new entries. Meanwhile, this verification allowed reducing the scope of the study and identifying the core concepts of classical TRIZ as well as applying the law of parsimony in practice.

During the next phase, the formal rules for ontology building [12] were used to create the first versions of separate ontologies for three sample concept domains of TRIZ: “System”, “Inventive Standard”, and “Contradiction”. It made it possible to test the data selected for consistency with predefined objectives of the study. Several versions of concept maps were discussed and improved during the study.

For modeling and visualization of the results, CmapTools software [13] was used. The software is based on the approach to creating concept maps to represent knowledge. The concept maps are supposed to express cognitive perception of relations that exists between concepts. The maps consist of hierarchic diagrams that include different concepts and links demonstrating how these concepts interrelate, focusing on showing the concept’s organization within the cognitive structure of an individual on a given subject.

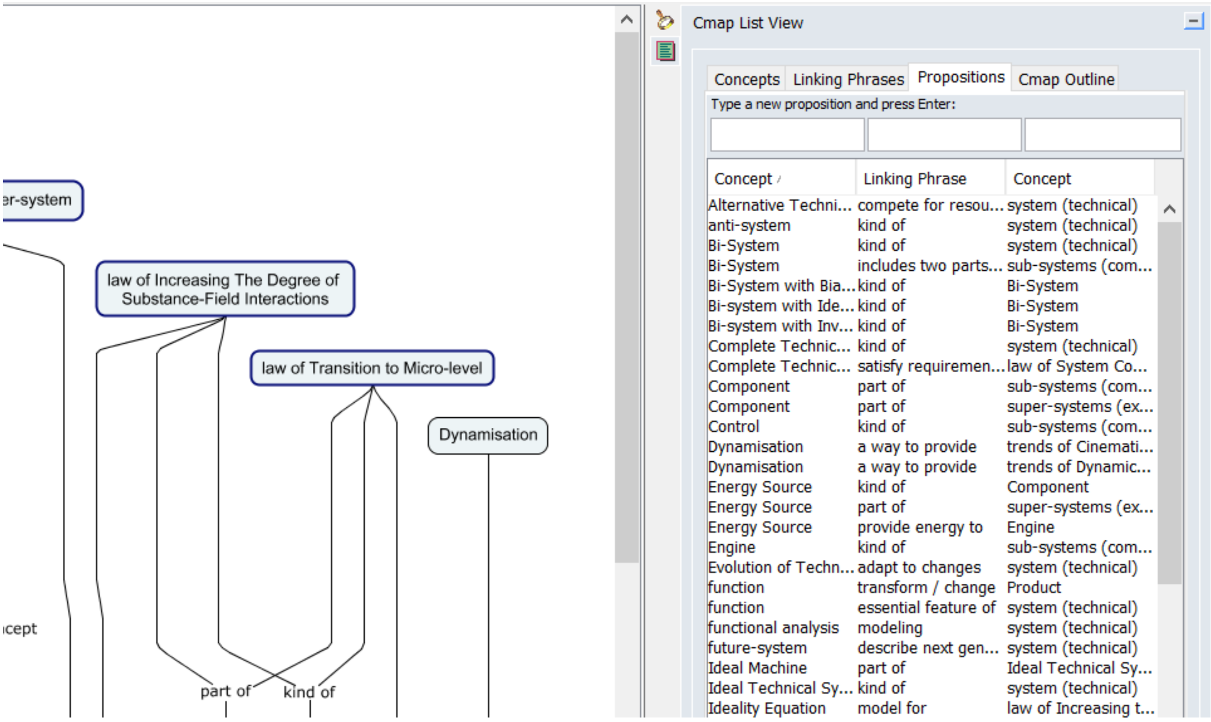

Fig. 1. Fragment of testing concepts (nodes) linking phrases (edges) and propositions with CmapTools

This way, a concept map becomes an instrument that shows the meanings attributed to the various concepts and how these concepts relate to each other within the context of a given body of knowledge. Concepts, and the Linking phrases, create an assertion (Propositions) that projects the meaning of the conceptual connection. [14]. An example of using CmapTools for modeling TRIZ Ontology is show in Fig 1.

After discussing and updating the ontologies for three TRIZ domains selected, the authors extracted described concepts and relationships and checked them for consistency with source of data in order to 1) identify missed relationships; 2) identify unused concepts; 3) plan how the domains are interconnected.

2.2. Concept relationships and their graphical representation

2.2.1. Types of Relations

The relationships between concepts are based on the hierarchical formation of the characteristics of a species so that the most economical description of a concept is formed by naming its species and describing the characteristics that distinguish it from its parent or sibling concepts.

There are three primary forms of concept relationships used in TRIZ Ontology:

- generic, or “kind of” relations,
- partitive, or “part of” relations?
- associative relations.

2.2.2. “is a kind of” Relations

Subordinate concepts within the hierarchy inherit all the characteristics of the superordinate concept and contain descriptions of these characteristics which distinguish them from the superordinate (parent) and coordinate (sibling) concepts, e.g. the relation of administrative, technical, and physical contradictions to contradiction concept.

Generic relations are depicted by an oriented graph with “is kind of” name of arrows (see Fig. 2).

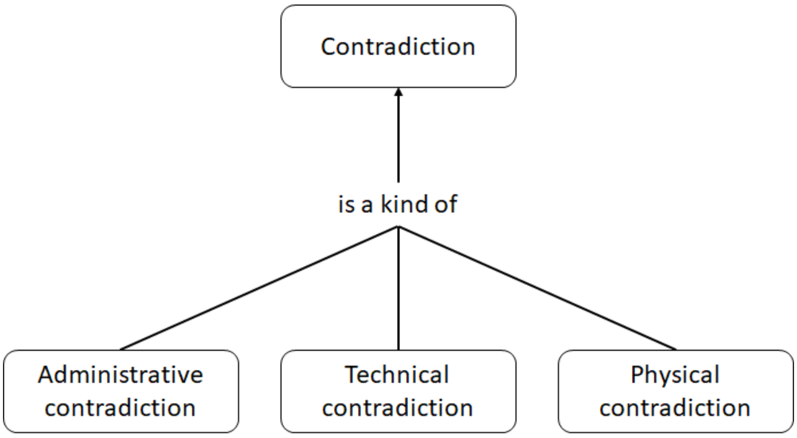

Fig. 2. Graphical representation of a “is a kind of” relation

2.2.3. *“is a part of” Relations*

Subordinate concepts within the hierarchy form constituent parts of the superordinate concept, e.g. system (technical) may be defined as part of the concept super-system and sub-system (component) as a part of the concept system (technical).

“is a part of” relations are depicted by an oriented graph with “is a part of” name of arrows (see Fig. 3).

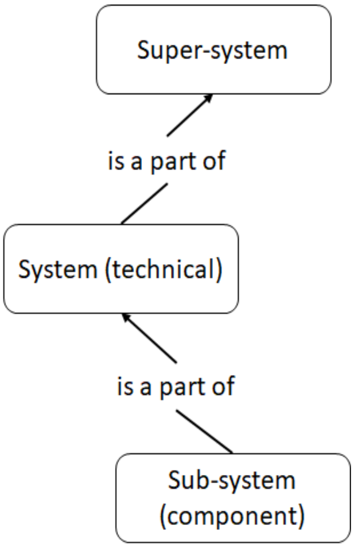

Fig. 3. Graphical representation of a “is a part of” relation

2.2.4. Associative Relations

Associative relations are helpful in identifying the nature of the relationship between one concept and another within a concept system, e.g. cause and effect, activity and location, activity and result, tool and function, material and product.

Associative relations are depicted by a named line with arrowhead at end (see Fig. 4).

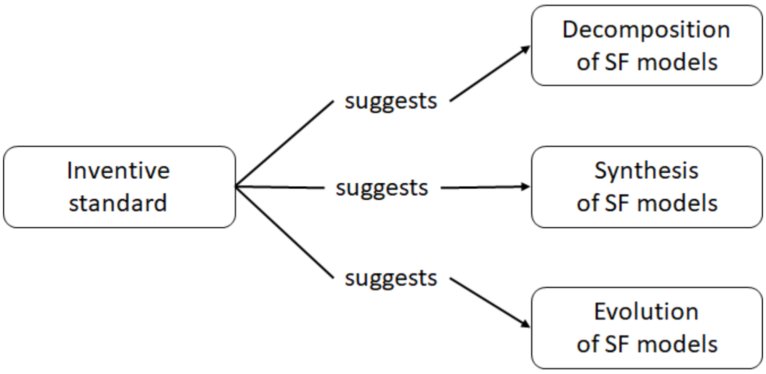

Fig. 4. Graphical representation of an associative relation

2.3. Concept diagram

TRIZ concepts have a lot of relations between each other. If we try to present all these concepts and relations in a single diagram then, as a result, we would get a very large non-readable and useless diagram with too many boxes and arrows.

In our approach, we built different diagrams for several selected TRIZ concepts such as *system*, *contradiction*, *solution* and *invention standard*. Each diagram represents a subset of TRIZ concepts and relations between them. The diagram on the Fig. 5 illustrates this approach for the *Technical contradiction* concept.

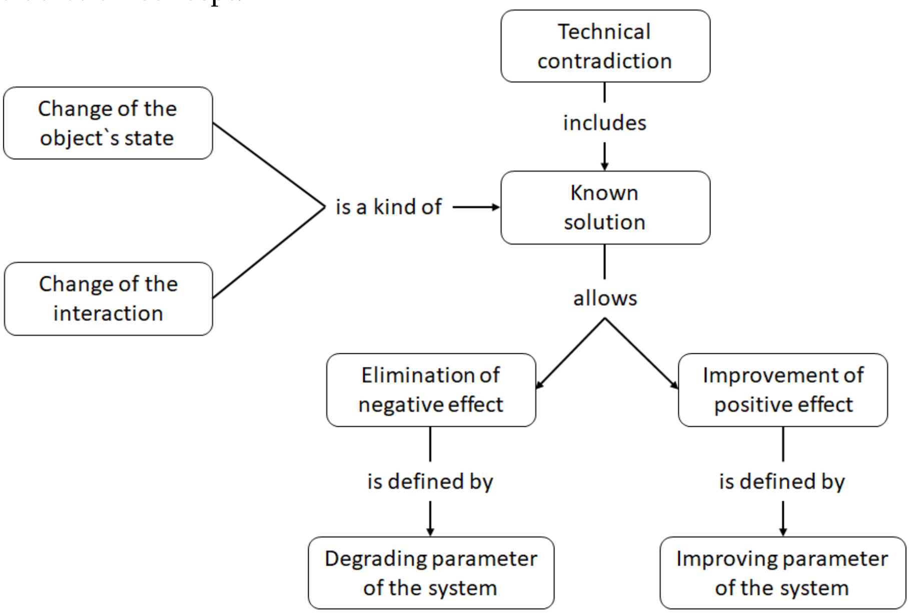

Fig. 5. Diagram for definition of the technical contradiction concept

Technical contradiction concept is selected as a basic concept on this diagram. Then we analyzed the definition of the *Technical contradiction* concept and identified the related concepts in it.

Additionally, we analyzed definitions of other TRIZ concepts that include related concepts as well. Once we detected another concept in the definition of the concept under consideration, we added this other concept to the diagram. In this way we detected a subset of TRIZ concepts and relations between them starting from the basic concept of the diagram.

3. TRIZ Concept Diagrams

This section contains several TRIZ concept diagrams and their descriptions.

3.1. System diagrams

Fig. 6 presents a fragment of ontology description for the concept of "System" in context of TRIZ. The concept of System in TRIZ is dissimilar from what is applied in System Science or Complexity Science [14]. Meanwhile we tried to depict relationships with concept of System used outside of TRIZ.

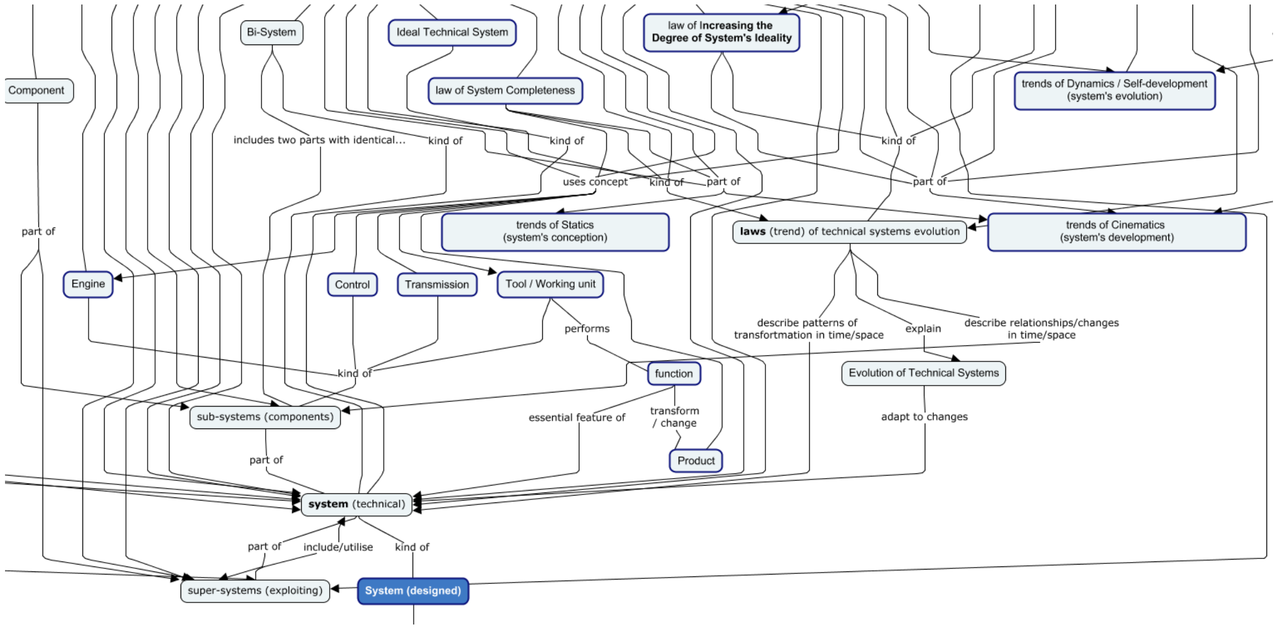

Fig. 6. Fragment of System concept diagram

Insights:

1. According to analysis of identified relationships among concepts from selected source of data, for defining a System the most important concept are super-systems and subsystems.
2. The most informative concepts according to developed description are: law of transition to super-system, law of harmonization, law of energy conductivity, energy source, law of non-uniform evolution of system's parts, law of transition to micro-level, law of system completeness, law of increasing the degree of substance-field interactions.
3. It was interesting to notice that the *law of increasing the degree of system's ideality* is neither the most informative nor the most definitive one when analyzing the number of meaningful links among concepts.
4. We believe that suggested ontology for concept of System in TRIZ-context will support development of quantitative theory for understanding structure and dynamics of inventive problem solving also known as creativity.

3.2. Contradiction diagrams

Fig. 7 displays the *Contradiction* concept in TRIZ.

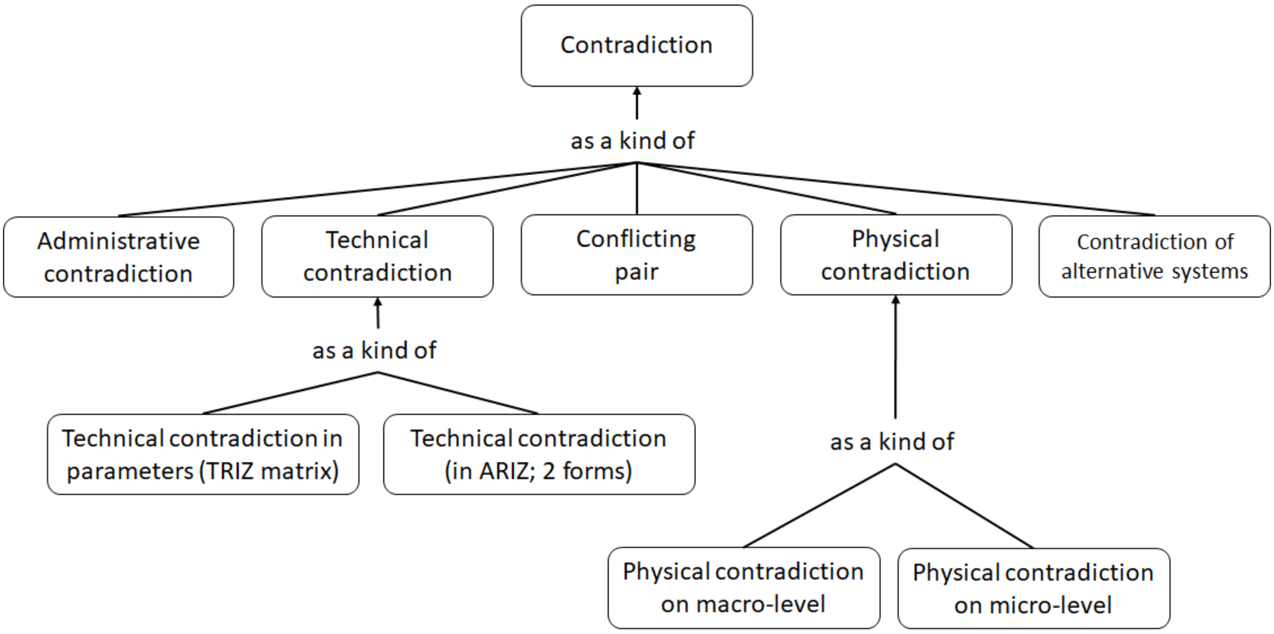

Fig. 7. Contradiction concept diagram

Insights:

1. In TRIZ literature, one can find three basic types of a contradiction: *administrative*, *technical* and *physical*. *A Conflicting Pair* concept is used in ARIZ-85C but in ontology context it is a specific type of contradiction with its own specific structure.
2. *Contradiction of alternative systems* concept was proposed by Gerasimov and Litvin in [16] and it is a specific type of contradiction as well. From one side, this contradiction has a semantic structure that is similar to the structure of technical contradiction used in ARIZ-85C. From the other side, this contradiction is defined for different technical systems (known solution) when the original technical contradiction is defined for one system in the consideration (one known solution and its change).
3. *Technical contradiction* concept can be defined in two different forms: a) in the form of two typical (pre-defined) engineering parameters which are used in Contradiction (TRIZ) Matrix; b) in the form that is used in Step 1.1 in ARIZ-85C.
4. Physical contradiction in ARIZ-85C can be defined in two different forms: on macro- and micro-level.

Diagram presented in Fig. 8 illustrates the semantic structure of *Physical contradiction* concept.

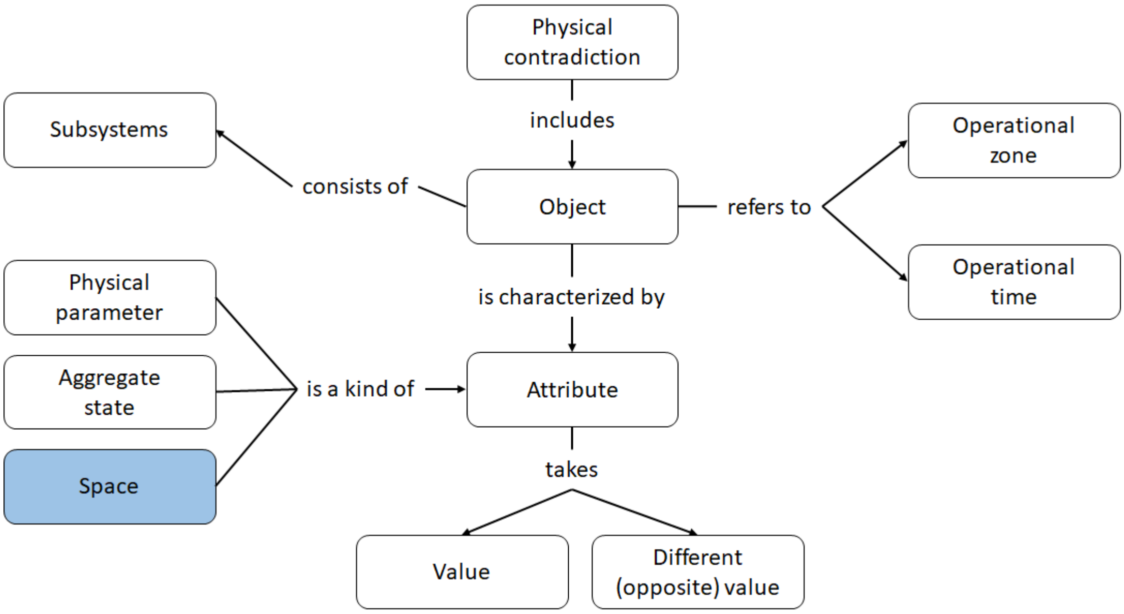

Fig. 8. Physical contradiction diagram

Insights:

1. Originally, in TRIZ (in ARIZ-85C) a physical contradiction was formulated for material object(s) in the operational zone during operational time. But one can see in the diagram that semantic structure of the physical contradiction is quite similar to the universal *Object-Attribute-Value (OAV)* concept defined in knowledge representation and engineering [17]. The OAV triplet is used in knowledge management not only for the definition of material objects in traditional engineering domains but for abstract objects in IT or business domains. The semantic structure similarity of *physical contradiction* concept from TRIZ and OAV concept allows us explaining different phenomena when problem owners successfully apply TRIZ techniques for solving contradictions in different domains with non-material objects such as data or business objects.
2. Integrating OAV with TRIZ was first proposed by Nikolay Khomenko [18]. His model was inspired by OAV and since it was adapted to OTSM[1]-TRIZ, it was called "Element - Name of Feature - Value of Feature" (ENV). However, his ideas about OTSM-TRIZ were not perceived by part of the contemporary TRIZ community. TRIZ Ontology provides an easy way to verify the correspondence of such ideas to the existing TRIZ body of knowledge.

3.3. Inventive standard diagram

Fig. 9 demonstrates relations between the concept map of "Inventive Standard" (also known as "Standard Solution" in TRIZ) and other concepts defined in the TRIZ Glossary. Only the first level of connections between the concept of "Invention Standard" and other concepts is shown.

[1] At the beginning of 1980s, more and more people started applying TRIZ not only to solving engineering problems but to different kinds of problems, even in their private life. It is why Altshuller started mentioning in his articles and manuscripts that TRIZ had to be transformed into the General Theory of Strong Thinking. OTSM is a Russian abbreviation for the theory and at the same time the title given by Altshuller himself. As our research was provided under his supervision and he approved of our results, in July 1997 Altshuller granted N. Khomenko permission to use the title "OTSM" in his research. This was done under the condition that each time the title was going to be used, its history had to be explained. It is why this comment appears here.

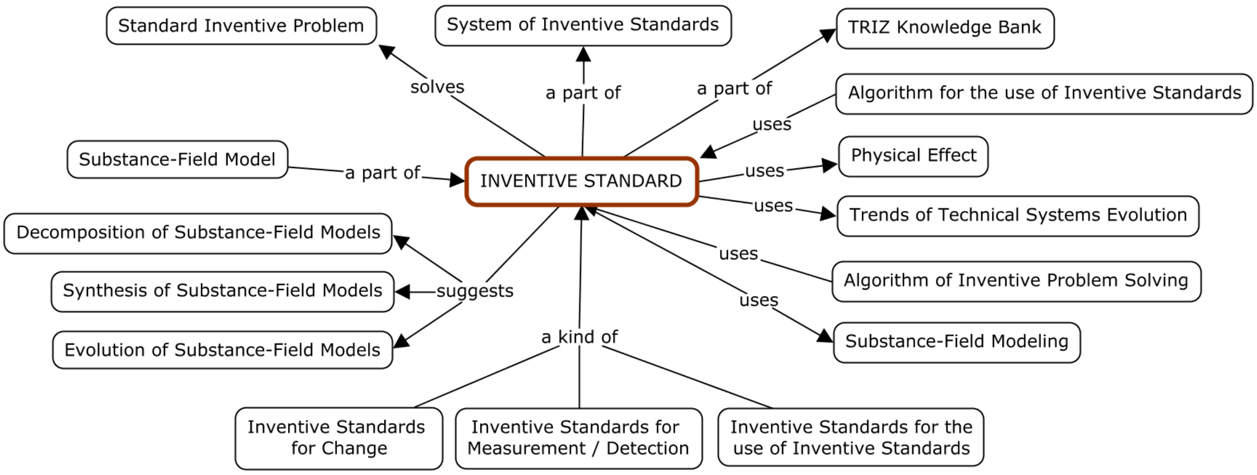

Fig. 9. Invention Standard diagram

Fig. 10 demonstrates relations between two concept maps: "Inventive Standard" and "Problem". It also includes intermediary concepts that exist between the two concepts, such as "Inventive Problem", or "Model of a problem". Only relations that are meaningful for relating both concepts "Inventive Standard" and "Problem" are shown for intermediary concepts. It is obvious that such intermediary concept as, for example, "Inventive Problem" has more relations with other concepts not shown in the diagram.

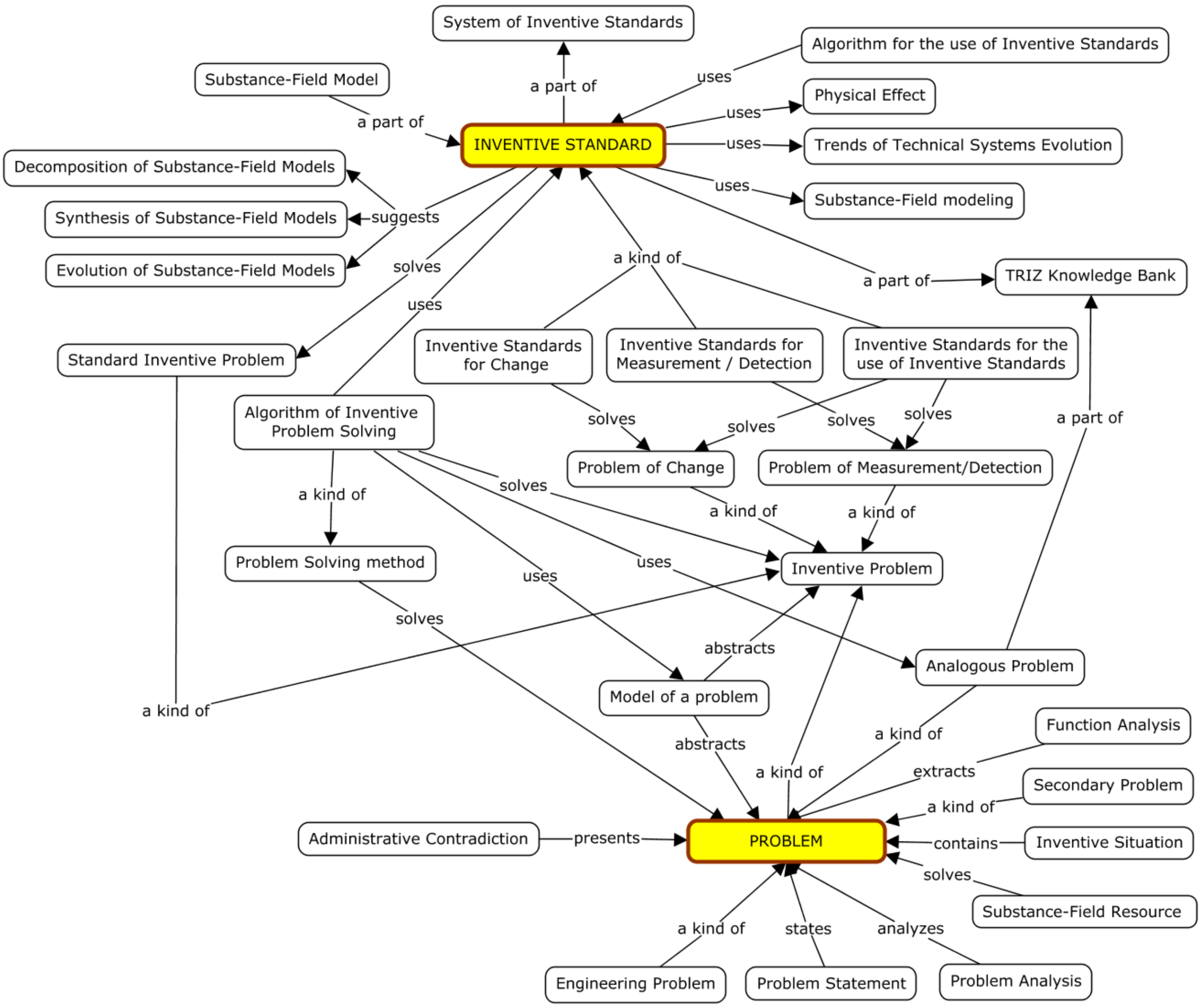

Fig. 10. Network of relations between two concepts: “Inventive Standard” and “Problem”

4. Conclusions

In this paper we made an attempt to demonstrate how the existing TRIZ concepts are related through building ontology of TRIZ knowledge. Although only the fragment of ontology has been developed so far, the results obtained seem to prove the concept identified.

The approach proposed enables establishing the relations between the concepts of TRIZ with concepts of other knowledge domains and develop systems of TRIZ Education and evaluation of TRIZ competence.

As seen during the study, while building relations between the TRIZ concepts it was noticed that definitions of some concepts in the TRIZ Glossary missed some important information. Therefore, it partly answers the question if TRIZ ontology can eliminate the deficiency of the existing and future dictionaries and glossaries.

Table 1 presents the number of covered concepts and propositions. The conclusion can be made that three of three categories of relationships (is a type of, is a kind of, associative) are enough to build a complete ontology of TRIZ.

Table 1: Data about studied concepts

Name of concept map	Number of concepts	Number of linking phrases	Number of propositions
System	45	46	89
Contradiction	37	20	34
Inventive standards	64	48	72
Solutions	16	6	14

The authors propose to continue this study through the development of TRIZ ontology and building the Glossary of TRIZ concepts as a collaborative project. Such the project can be performed with the help of members of the TRIZ Community on the basis of aka-Wiki platform [19].

References

1. Souchkov V. "Glossary of TRIZ and TRIZ related Terms". The International TRIZ Association - MATRIZ, 2018.
2. Gruber, T.R. "A Translation Approach to Portable Ontology Specification". *Knowledge Acquisition* 5, 1993, 199-220.
3. Oxford Living Dictionary of English. https://en.oxforddictionaries.com/definition/ontology
4. Noy N. F. & McGuinness D.L. "Ontology Development 101: A Guide to Creating Your First Ontology" Stanford University, Stanford, CA, 94305. https://protege.stanford.edu/publications/ontology_development/ontology101-noy-mcguinness.html
5. Souchkov V. V., Alberts L. K. & Mars N.J.I. "Innovative engineering design based on sharable physical knowledge". *Artificial Intelligence in Design'96: Proceeding of the International Conference Artificial Intelligence in Design*, Stanford University, USA, Kluwer Academic Publishers, 1996. pp. 723-742.
6. Bultey A., De Bertrand de Beuvron F. & Rousselot F. "A substance-field ontology to support the TRIZ thinking approach". *International Journal of Computer Applications in Technology* 2007; 30. pp. 113-124.
7. Cavallucci D., Rousselot F., Zanni C. "An ontology for TRIZ". *Procedia Engineering*, Volume 9, 2011. pp. 251-260.
8. Koswatte R. C., Paik I., Banage T. G. S. Kumara, Siriweera T.H.A.S. "Meta-ontology for innovative product design with semantic TRIZ". *2015 International Conference on Electrical and Information Technologies (ICEIT)*, 25-27 March 2015, Marrakech, Morocco. pp. 379-384.
9. Kucharavy D. OTSM-TRIZ Glossary, Working version.
10. Altshuller G.S. "Theory of Solving Inventive Problems: Report "TRIZ-88". 1988. (In Russian).
11. TRIZ Terms. in Electronic Book "*Introduction to TRIZ. Main Principles and Approach*". Ver. 3.0. Official G.S. Altshuller Foundation. https://www.altshuller.ru/e-books/
12. "ISO 9000-2005(E) Quality Management Systems - Fundamental and Vocabulary." 2005. Geneva, Switzerland: ISO 2005.
13. Joseph D. Novak & Alberto J. Cañas. "The Theory Underlying Concept Maps and How to Construct and Use Them". 2008. https://cmap.ihmc.us/docs/theory-of-concept-maps.php

14. Gouveia V. & Valadares J. “Concept Maps and the Didactic Role of Assessment”. *Concept Maps: Theory, Methodology, Technology, Proc. of the First Int. Conference on Concept Mapping*. Pamplona, Spain, 2004
15. Map of the Complexity Science, 2018. https://www.art-sciencefactory.com/complexity-map_feb09.html
16. Gerasimov V. & Litvin S. “Why does engineering need plurality?” *The Journal of TRIZ*, 1, 1990. 11-30. (In Russian).
17. Fritz Lehmann. “Semantic Networks”. *Computers & Mathematics with Applications*. Vol.23, No. 2-5, pp. 1–50, 1992
18. Khomenko, Nikolai & Alexander Sokol. “New Models and Methodology for Teaching OTSM-TRIZ.” *International Conference of the Altshuller Institute: TRIZCON-2000*. Nashua: New Hampshire, USA, 2000.
19. https://en.wikipedia.org/wiki/Wiki

Communicating Author:
Andrey Kuryan, Andrei_Kuryan@epam.com