Advances In The Application of Computational Linguistics for TRIZ Practice

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Abstract

Altshuller's information fund concept is central to TRIZ. The application of TRIZ relies upon the individual practitioner's familiarity and facility in leveraging knowledge from the information fund. However in practice, engineers are constrained by local knowledge and the psychological inertia that this parochial view engenders.

Advances in computational linguistics are elevating the practical use of TRIZ to new heights providing knowledge workers with unprecedented access to the knowledge that spurs innovation through TRIZ practice. In this session, the state of the art of computation linguistics for TRIZ and problem solving is presented with examples of this application from industrial experience.

1. Introduction

Altshuller's information fund concept is central to TRIZ. The development of TRIZ stems from the leverage of accrued global knowledge. Altshuller tapped in to some of this knowledge in his well known patent studies from which derive the basic tenets of TRIZ. In addition to this foundation, Altshuller prescribes that the successful TRIZ practitioner must continuously expand his own mastery of global knowledge which can be leveraged in the inventive process.

The application of TRIZ relies upon the individual practitioner's familiarity and facility in leveraging knowledge from the information fund. However in practice, engineers are constrained by local knowledge and the psychological inertia that this parochial view engenders. This tendency has been intensified by the specialization of knowledge workers.

Applied computational linguistics has promised to help designers and engineers more effectively apply TRIZ by providing knowledge workers with unprecedented access to the knowledge that spurs innovation through TRIZ practice. Recent advances in computational linguistics in the area of high-level concept extraction and design intent based retrieval to specific innovation tasks allow for just-in-time knowledge delivery that accelerates problem analysis and resolution. Understanding the state of the art of computation linguistics and its applicability to TRIZ practice and problem solving is promises to enable a new and broader application of structured problem analysis and solving.

2. TRIZ Practice

To solve a problem effectively, one needs to first understand the problem. This means understanding that the problem being examined is the correct one, defining the goal of the desired solution, and expressing the problem statement in a way that allows the solver to map the problem situation to the solution goals naturally. TRIZ is a well developed system to approach problems in a structured way and to identify inventive solutions to these problems.

To assist its practitioners in the endeavour of problem solving, TRIZ concepts have been distilled into a number of tools and algorithms. One of the great powers of TRIZ is that the tools for this methodology provide a framework and a language for describing and understanding problems. Furthermore, TRIZ provides motivation for the goal of problem-solving. The basic concept of Ideality is an expression of such a goal. The ideal system will possess certain characteristics. While the ideal system is not itself a goal, it provides a useful way of planning the goals that will drive the evolution of the solution to a problem [1].

In practice, TRIZ tools are often supplemented by other methods of problem refinement. TRIZ becomes embedded in an ecosystem of methodologies of problem understanding. Techniques of root cause analysis, value engineering analysis, Design for Six Sigma and others are frequently employed partners of TRIZ in the design and problem solving word. Yet, the wide spread adoption of TRIZ has been elusive. To better understand this difficulty, let us consider one TRIZ tool as an example.

System functional modelling has become a very widely used tool to help implement TRIZ and to gain better insights into how to leverage the Ideality concept. Ideality considers the ratio of useful functions and harmful functions of a system. Specifically, Ideality is often expressed with the formulae of a form similar to Ideality =

Useful functions / (Harmful functions + Cost) [2, 3]. It is this relationship of useful and harmful functions that makes system functional modelling a tool that is so well suited for TRIZ. In the functional model, the practitioner explicitly identifies the useful and harmful functions in the system, thus providing an excellent vehicle for understanding how to move the system in the direction of the Ideal Final Result.

Unfortunately, this tool is not used by all TRIZ practitioners. Why? Because the collective experience with system functional modelling suggests that it is not easy for the novice practitioner. In a quick survey of TRIZ practitioners, experts seemed to find little difficulty with functional modelling[1]. Non-expert practitioners, on the other hand, reported difficulty with both system component definition and function specification. The expert practitioners also reported observing this issue when working to assist non-experts.

What is behind this gap in the experience with system functional modelling? The answer seems to lie in the availability of actionable local knowledge. Expert practitioners have developed a lexicon of functions and parameters that are readily applicable to broad situations. The non-expert, lacking this personal resource, struggles to find the way to express their understanding of the system. If knowledge is the problem, can we look to the TRIZ Informational Fund for the solution?

3. The TRIZ Information Fund

Altshuller teaches us that the problem-solver needs to have a wealth of actionable knowledge available to be most effective [4]. This is the basis of the TRIZ Information Fund. The fund comprises the full scope of literature that is produced and available through a variety of sources: published collections of scientific effects and their applications, patent literature, captured industrial experience, to name a few [5]. The fund is as rich as it is deep. Unfortunately, the strength of the fund is also its weakness.

Let us consider the single resource of patent literature. It is estimated that over 80% of the world's technical knowledge is captured in existing patent literature[2]. The body of patent literatures comprises many millions of documents. How can any one practitioner study this body effectively and have access to precisely the right information at precisely the time when that information is needed?

Until recently, there was no good answer to this question. The patent literature was a poorly utilized source of knowledge and solution ideas. However, recent advances in computation linguistics have changed this situation. Modern computers can process and organize these millions of documents with great speed. Semantic indexing technology provides the mechanism to instantly locate specific facts and information that are directly relevant to a technical question. These technologies not only make the dream of a useful TRIZ Information Fund a reality, they also create the opportunity to transform the information fund from a static repository of information to an active knowledge source that is integrated with the objective of a problem-solver's activities.

4. Brief History of Computational Linguistics

4.1 From Ignominious Origins

It has been said that all of man's greatest inventions have been created in service of prosecution of war. Unfortunately, the area of computational linguistics does not provide any better view of human creativity. The field began as a specific branch of the study of natural language processing (NLP) for the purpose of machine translation of documents.

This field of research was heavily funded by the United States and the former Soviet Union during the cold war years. The goal was simply to be able to better spy on the other side. However, the early work in this area was far from effective. These early failures gave rise to many often cited examples of the difficulty of achieving the goals of NLP. One early test translated the maxim, "The spirit is willing, but the flesh is weak," from English to Russian and then back to English. Unfortunately, the resulting English text after this round trip translation read, "The wine is fair, but the meat is over cooked."

Undaunted by the challenges of NLP, many pioneers continued to move the state of the art forward.

4.2 First systems of response

In order to explore the cognitive processes of language recognition, some researchers explored the concept of interactive dialog engines. These engines simulated a conversational interaction model with a human participant. One of the best known such engines was named ELIZA.

Built by Joseph Weizenbaum, ELIZA was design to play the role of a nondirective psychotherapist. The human would play the role of the patient in the exchange.

[1] Informal survey conducted by author during period from June 2006 through February 2007. Expert classification is applied to specialized TRIZ consultants or engineers who devote more that 50% of their time to TRIZ-related analysis. Nonexperts comprise novice TRIZ practitioners and experienced, but occasional, TRIZ practitioners.

[2] Source: European Patent Office

In these simulated conversations, ELIZA was able to carry on very realistic exchanges.

The effectiveness of ELIZA was made possible by a large database of word and action rules that guided the conversation to a relatively small number of topics that were likely to be significant in their emotional context. However, it was all a ruse. ELIZA did not actually understand anything about the conversation in which it took part. In fact, Weizenbaum's choice of psychotherapeutic conversation was made explicitly because it represented a model of dialogue in which one of the participants is free to have no knowledge of the real world [6].

4.3 Beginnings of understanding

It was widely accepted that in order to crack the code of natural language, the NLP engine would need to have some understanding of the natural world and its workings. Research in NLP began to experiment with cognitive models that incorporated knowledge representation systems.

Terry Winograd's SHRDLU was one of the most successful early systems of this type. Like ELIZA, SHRDLU engaged with a human in conversation. However, now the conversation centered around a virtual world and the manipulation of the objects that were contained in that world [7].

As an example of NLP, SHRDLU was extremely impressive. It showed that using a model of global knowledge to enable a program to distinguish the context and meaning of specific statements was possible. While SHRDLU's world was very small and specific, this demonstration of storing and applying knowledge about the world was a major advance in NLP.

4.4 A theory of conceptual modeling

In order to make NLP more broadly applicable, it was important to generalize the models of capturing and representing both global knowledge and specific context. In the 1970's, the Conceptual Dependency Theory was developed as one approach to modelling conceptual understanding. This theory of representation of the meaning of sentences derives from a few basic postulates [8]:

- Any two sentences that are identical in meaning, regardless of language, should have only one representation
- Any information that is implicit in the sentence must be made explicit in the representation of the sentence
- Conceptualizations are the underlying meaning propositions of language and may be either active or stative
- Active conceptualizations have the form: Actor Action Object Direction (Instrument)
- Stative conceptualizations have the form: Object State

The foundations of Schank's work in Conceptual Dependency Theory have had wide effect in the practice of computational linguistics.

5. State of the Art and Recent Advances

5.1 Applying Semantic Analysis to Concept Retrieval

The relevance of NLP to problem solving was not established until the techniques moved from the abstract and academic world of language understanding to the more pragmatic world of concept retrieval. The recognition that the canonical representation of sentence meaning could be used as a method of identification of concepts for the purposes of retrieval gave rise to a new era in unstructured data management.

By defining an extended Subject-Action-Object (e-SAO) model for the canonical representation of sentence meaning, technology to index and retrieve knowledge could be created to answer specific questions [9]. The first searching models did not need global knowledge to achieve very impressive results. While the systems are subject to error due to the intrinsic ambiguity of language (called the *word sense disambiguation problem*), algorithms for matching e-SAOs and ranking results have achieved precision and recall rates exceeding competitive technologies.

Despite the strength of the e-SAO based concept retrieval technology, mining answers to high-level concept based questions can still be problematic. Consider the question: "What causes indigestion?" Clearly, the sentence "Overeating causes indigestion," provides a direct answer. However, the sentence "Indigestion is a symptom of gastric dilatation and volvulus syndrome," may also be of interest even though the meaning of the sentence is very distinctly different from the former example. Such high-level concept based research requires a more advanced system of meaning correlation.

5.2 Extraction of high level concepts

5.2.1 Cause~Effect

In order to answer questions such as, "What causes indigestion?", a deeper analysis of the semantic context of the text is required. Here a secondary analysis of the e-SAOs extracted by semantic analysis is used to recognize specific cause and effect relationships. This secondary analysis is performed using a specialized linguistic data base that embodies world knowledge of what constitutes a relationship of causality [10].

Recognized causal relationship may subsequently be aggregated and organized to make their retrieval in solution searching contexts easier. This concept retrieval can look in either direction along the causal chain—from cause to effect or from effect to cause.

5.2.2 Mereology & Interaction Models

Similarly, certain classes of questions are answered by information about the structure of a system. The extraction of information related to the mereological relationships and the interaction models that define systems also relies on captured world knowledge represented by linguistic rules. In such a system, the linguistic rules base allows the recognition of e-SAO structures that denote structural relationships, declaration of the functions between entities, and the parameterized effects of the functions on the systems member entities [11].

For example, let us consider the sentence: “The car is equipped with the engine.” In this example, we can see that the noun phrase “the car” is related to the noun phrase “the engine” by the verb “equipped”. It is further the case that the semantics of the verb & prepositional phrase structure confers upon the verb “equipped” a language sense that denotes a whole-part relationship. Thus it is concluded that “car” and “engine” participate in a whole-part relationship, where “car” is the whole and “engine” is the part.

6. Applying Computational Linguistics to TRIZ Practice

The utility of concept indexing and retrieval enabled by computation linguistics for TRIZ practice is very broad. In TRIZ practice, problems are abstracted to enable the identification of generic solutions. This notion of abstract problem representation is at the core of applying computation linguistics to the arena of problem solving.

6.1 Automated Concept Sourcing

Computer based problem analysis and modelling tools exist to help problem solvers explore the innovation challenges they face. Many of these tools provide methods for the graphical representation of problems and systems. These programs generate internal representations of the problem space which are themselves abstractions of the original problems.

An example of such a system is a functional modelling tool. Such a tool captures the components and interactions within a system. However, there is a duality in the information embodied in the model. An undesirable function also denotes a problem state. The components which are related by the undesirable function and the function itself can be said to form a 3-tuple that can also be said to have equivalence to a basic SAO structure. This rough equivalence allows the stored system model to be manipulated in service of the automatic sourcing of concepts that can be used to address the problem state.

This type of model and SAO mapping is not unique to functional models. Any internal representation of a problem state or system is a candidate for automated problem extraction and query formation that can help transform static data repositories into active sources of actionable knowledge [12]. Solution concepts can be served up to engineers when they need them in the context of their innovation analysis.

6.2 Contradictional problems and Semantic TRIZ

Some problems have a contradictional aspect to them. In these instances, improving one aspect of a system leads to a degradation of another aspect. TRIZ teaches us that we do not have to settle on a compromise approach in these situations. The TRIZ inventive principles and patterns of system evolution are tools that help uncover non-compromising solution approaches.

It is useful to be able to identify instances in the literature when such a contradiction has been addressed. One approach to identifying such practical examples has been described as *Semantic TRIZ* [13]. In this approach, a semantically indexed knowledge database is used as a contradictional question answering engine.

Verbitsky suggests that such an approach helps designers make the often non-intuitive leap from generalized concept to specific solution concept. Because the semantic knowledge base is assumed to cover the literature more comprehensively and with more currency, it is also argued that Semantic TRIZ insulates the practitioner from any statistical bias or instability in the underlying TRIZ models that may exist.

6.3 Problem analysis with Cause~Effect

Common TRIZ practice often sees TRIZ methodology used in concert with other engineering disciplines and tools. An example of such a tool which sees very broad acceptance in modern practice is root cause analysis. Practiced in many forms such as the 5-Why method and Fishbone Diagramming, root cause analysis seeks to understand the context of a problem and ensure that solving efforts are focused on the right issues.

Traditional root cause analysis is subject to variation in the effectiveness of the practice and the quality of the outcome. This variability stems from the dependency on brainstorming as the mechanism to drive identification of causes and sub-causes of events. Brainstorming introduces a human element. As a result, constraints of local domain knowledge, psychological inertia, and other human factors taint the breadth and objectivity of the analysis. The application of semantic knowledge retrieval can help address this variability and help practitioners perform root cause analysis more rapidly and with more reliable results.

One system for knowledge enabling root cause analysis makes use of high-level concept extraction and capture technology to identify cause-effect relationship facts in natural language text and creates a specialized database of causality facts. This database is searchable to find the potentially matching elements of any half of a cause effect relationship. Thus given a cause element, a list of potential effects can be generated. Conversely given an effect element, a list of potential causes can be created. The system further presents results of a causality search in an aggregated manner so as to provide the user guidance in analyzing the results [14].

Using such computer aided systems of analysis has great benefit to designers and engineers. The semantic concept retrieval provides access to vast quantities of pre-analyzed information beyond what the practitioner could expect to review through traditional means. This high quality information access results in faster, higher value analysis.

A similar approach can be used for predictive failure analysis as well. Risk management methodologies such as Failure Modes Effects Analysis (FMEA), HAZOP, Hazard Analysis and Critical Control Points (HACCP), and other similar practices can be greatly enhanced through the knowledge enablement of applied computational linguistics.

6.4 System Analysis

Function Modelling is another practice that has become common place in TRIZ practice. Its benefits for capturing and exploring the design intent of a system are well understood. In the system of function modelling, the engineer may perform several tasks including: identifying components, finding component interactions, simplifying the system through trimming (reducing harmful functions), and extending the system (increasing useful functions).

Using the technology described earlier for extraction of structural and interaction relationships, many of the key elements of function modelling can be simplified. Practitioners can use computer generated component lists to validate model contents. Derived interaction data can support the development of a precise model of the system under investigation.

New technology configurations may also be explored by examining possible functions that interact with components outside the system being examined. Each such new function-component interaction represents a new business opportunity as it could lead to either a new product extension or an ancillary product.

7. Application Examples

By way of example, let us consider two recent applications of knowledge enabled innovation from contemporary industrial practice.

One company in the bedding industry wanted to find a new innovation in the design of a box spring. Understanding that this product is difficult for its users to move and transport, the engineers decided to consider how to make a box spring that was more easily manipulated and moved. As this problem is considered, it clear to see the contradiction in the system. The box spring must be rigid for proper operation, but it must be pliant to make it easy to manipulate. Using knowledge enabled technologies describe herein, the engineers were able to quickly identify concepts that allowed them to create a folding box spring. The company has now introduced this product to market and created a new category in the process.

In another situation, a leading petrochemical company was investigating the development of a large scale, commercially viable approach to producing biofuel from marine algae. The company was faced with many unique problems based on the scale of the planned operation. Methods for processing vast quantities of water, methods for high efficiency algae recovery, and methods for high volume drying of high moisture biomass all need to be developed. Applying TRIZ approaches of function modelling and other tools allowed the researchers to understand the available resources and options for implementation.

8. Conclusion

TRIZ is a well developed and proven system for inventive problem solving. Its foundation lies in the systematic leverage of global inventive experience. The essence of this experience is captured in the various TRIZ tools.

Another key element of the TRIZ method is the Information Fund. However until recently, the Information Fund has been only a concept. Recent advances in computational linguistics have now made the TRIZ Information Fund a practical reality.

Advanced methods of semantic information processing create reusable databases of concepts that can be delivered to practitioners in a just-in-time manner which supplements the local expertise of the TRIZ practitioner. The systems that provide these capabilities have proven their utility in practice. Practitioners have access to global knowledge that can be leveraged in the context of their innovation work in a way that transcends language barriers [16].

The impact of these technological advances to TRIZ practice include both enabling experienced practitioners to explore concepts more quickly and thoroughly, and reducing the skill barrier that has deterred many designers and engineers from employing TRIZ disciplines.

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Presenter's Profile

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