Innovation and Knowledge Management: using the combined approach TRIZ-CBR in Process System Engineering.

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Abstract

In this article, a TRIZ based model is proposed to support the innovation and knowledge capitalization process. This model offers a knowledge base structure, which contains several heuristics to solve problems, synthesized from a large range of domains and industries and, also, the capacity to capture, store and make available the experiences produced while solving problems.

Keywords: TRIZ, Innovation, Chemical processes, CBR.

1. Introduction

As enterprises attempt to improve their capacity to innovate and consequently, their business performance, their attention focused more and more in some intangible assets: their knowledge resources. According to Smith [1], innovation's outcome depends solely on the creativity and knowledge of talented employees and the effectiveness of the methods and processes that support their work.

The knowledge dimension has been covered and supported by a new discipline: Knowledge management (KM). KM encompasses several mechanisms to systematically managing the knowledge that evolves within the enterprise.

With regard to creativity, the problem's complexity is continuously increasing and the time for solving it, decreasing. In spite of this increasingly complexity, problems still have been faced using traditional psychological based approaches like brainstorming, the trial-and-error search method, among others [2]. Thus, an approach able to generate ideas for systematically solving problems is needed. Recently, a new approach that conceives innovation as the result of systematic patterns in the evolution of systems has emerged in the industrial world: the TRIZ theory. TRIZ or Theory of Inventive Problem Solving creates an environment where individuals can systematically solve problems and improve decision-making. In this paper, both elements –creativity and knowledge-are integrated in a model that combines several TRIZ advantages and the process issue from the Case-Based Reasoning, for creating a support for the innovation and knowledge capitalization process. This combined approach is applied in the Process System Engineering field.

2. TRIZ, the Theory of Inventive Problem Solving

This new vision about technological problems and scientific technical evolution has its foundations in the Soviet Union in 1946; when Genrich S. Altshuller, a young employee was working in the patent department of the Soviet navy. He was convinced that methods for systematically innovate were available. With this objective in mind, Altshuller began the search for those methods and in the process; He created the first innovation knowledge base.

The particularity of this new approach for solving problems, settles on its origins. While developing his theory, Altshuller analyzed and synthesized knowledge from four sources: (1) an analysis of over 3 million worldwide patents; (2) the examination of available tools and methodologies for solving problems, with the aim to create an entirely new approach; (3) an inventor's creative mental patterns analysis, with the objective to extract the most creative solutions and strategies to solve problems and (4) an extensive scrutiny in scientific literature that revealed an enormous knowledge body that could be applied for solving problems [3].

The psychological strategies and technical knowledge, extracted from the history of technological and social evolution, were transformed to be reusable and then, embodied in TRIZ. As result, TRIZ theory encompasses a set of fundamental concepts, a collection of tools and heuristics to solve complex problems and several laws or trends of evolution for technical systems. Among main TRIZ concepts are:

- The evolution of all technical systems is governed by objective laws.
- The concept of inventive problem and contradiction like an effective way to solve problems. This also means that any problem could be modeled as contradiction.
- The innovative process can be systematically structured [4].

Consequently, TRIZ has the capacity to considerably restraint the search space for innovative solutions and to guide thinking towards solutions or strategies, that have demonstrated its efficiency in the past in a similar problem and, in this process, to produce an environment where generate a potential solution is almost systematic [5]. In this paper, a TRIZ tool named Contradiction Matrix has a central role. This tool and its intrinsic concepts are described in the next section.

2.1. The Contradiction Matrix
While exploring the patents database, Altshuller found a common denominator between several patents, in different technological disciplines: the fundamental problem that characterizes these inventions was the same, and was solved in the same way. He also found that a limited number of parameters - 39 Generic Parameters- and solving principles -40 Inventive Principles- could be used to characterize any problem.
Consequently, Altshuller shows that knowledge from patens databases, could be extracted, transformed and arranged in such a way, that its reutilization was accessible by any person in any domain. This reflection guided the creation of several TRIZ tools and concepts, between those, the contradiction concept and the Contradiction Matrix. A contradiction occurs, when any tentative for improvement in a system parameter, has an undesirable degradation in a second one also useful; so an inventive problem is one that contains at least one contradiction and an inventive solution, is that which overpass totally or partially a contradiction. Those concepts determine one of TRIZ milestones: problems are solved without compromise or tradeoff [2].
The 39 Generic Parameters make possible to model any problem as a contradiction and the 40 Inventive Principles, permit to restrain the solution space for effectively direct the creative effort to solve problems. Those elements are organized in a 39*39 matrix, named Contradiction Matrix[*] (Table 1).

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[*] An extensive description is available at the TRIZ Journal. www.triz-journal.com

	1… Weight of moving object	2 Weight of stationary object	…39 Productivity
Degraded **A** **B** **To improve**			
1. Weight of moving object			35, 3, 24, 37
39. Productivity	35, 26	28, 27	

Table 1: A Contradiction Matrix fragment

To use this matrix, firs the parameter "A" – in lines-that has to be improved is identified and then, the parameter "B" –in columns- which is deteriorated. The intersection between line and column isolate a cell, that encloses the inventive principle or principles that have been successfully applied to resolve this particular conflict in analogous problems. Those principles are represented with a number and hierarchically organized in every cell.

Example: This example concerns the performance of a low pressure chemical vapor deposition reactor (LPCVD) with a vertical configuration (figure 1-A). While analyzing its performance a contradiction was identified: to improve the quality of the silicium film in the wafer, the gap between wafers must be large, in consequence, the quantity of wafers inside the reactor is reduced affecting productivity. The problem was stated as "To increase the productivity in the reactor without radically modify its shape". Using the Contradiction Matrix and *Productivity* as feature to improve and *Shape* as degraded parameter, is possible to identify four inventive principles to solve this contradiction in a hierarchical order: 14 (spheroidality), 10 (Prior action), 34 (Rejecting and regeneration parts) and 40 (Composite materials). Principle 14 says: replace linear parts or flat surfaces with curved ones and cubical shapes with spherical shapes, replace linear motion with a rotating motion; utilize a centrifugal force. The interpretation of this principle reveals that the useful working area should be conceived as a spherical one. This concept is showed in figure 1-B [6]. The obtained reactor has a 90 wafers capacity while the typical one has a 25 wafers capacity; consequently, the productivity is radically improved.
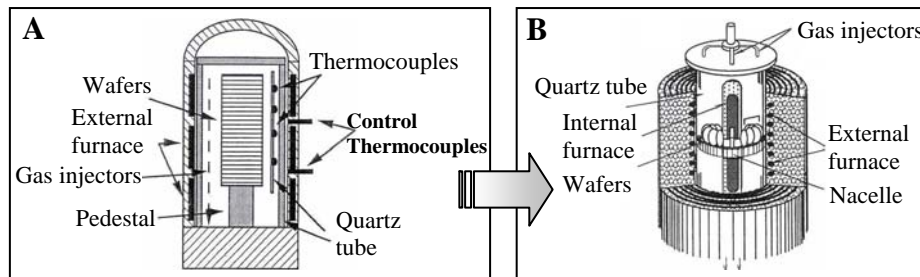

Figure 1: The proposed solution

TRIZ practitioners have proved that applying common solutions for the resolution of contradictions, identified as effective when applied to parallel problems in the world patent base, radically improves the design of systems and products [4]. This fact implies that problems sharing the same contradiction are similar in nature and for this reason; one problem's solution could be exported to other problems containing the same contradiction. According to Terninko, 95% of inventive problems in any domain have already been addressed and solved in some other field [4].

Nevertheless, even if TRIZ has in its structure the knowledge extracted from several technical domains and scientific disciplines, it does not have any component exclusively

conceived to capture and reutilize the knowledge deployed or created while solving problems. For dealing with this lack, a synergy with another approach is desirable, the most indicate to accomplish this objective is the Case-Based Reasoning (CBR).

3. The Case-Based reasoning (CBR)

In the CBR process, problems are solved by reusing earlier experiences [7]. In this process, new problems are compared with cases or specific problems encountered in the past, to determine if one of the earlier experiences can provide a solution. If a similar case or set of cases exists, their solutions must be evaluated and adapted to find a satisfactory one. This approach has proved its utility to support design activities, equipment selection and also knowledge management activities among others [8], [9], [10]. The CBR as methodology for problem solving encompasses four essential activities: retrieve, reuse, revise and retain [7]. In this process (figure 2), the problem solving process starts with an input problem description or new confronted case [10]. This description is used to –Retrieve- a problem or set of previous solved problems (cases), stored and indexed in the memory. Then if one or various stored cases match with the initial problem, the most similar case is selected to –Reuse- its solution. Subsequently, the derived solution must be -Revised-, tested and repaired if necessary in order to obtain a satisfactory result. Finally the new experiences which comprise failure or success, strategies to repair and implement the final solutions, among others particular features, are -Retained- for further utilization and the previous cases memory is updated.
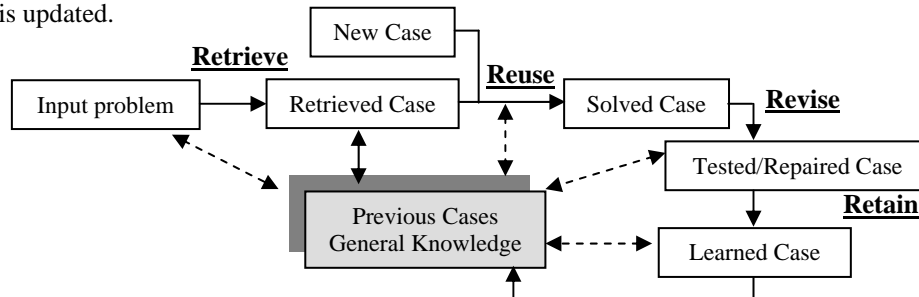

Figure 2: The CBR cycle

One of main disadvantage in a CBR system is intimately relied on its memory. In other words, a CBR system dealing with a problem that has never been faced up in the past will not be capable to offer an efficiency initial solution. To downgrade this inconvenient, a tool capable to define and propose some search directions for any kind of problems is advisable, in this case, the Contradiction Matrix. The synergy between those TRIZ tools and the CBR process is showed in next section.

4. Creating a synergy between TRIZ and CBR

The complementary characteristics between TRIZ and CBR allow the creation of a synergy. In this process, the initial problem is described and modeled as a contradiction. Then, this contradiction and some other elements derived from the problem description are used to retrieve a similar case in the memory. This search could offer or not a similar case. Consequently, at this state of the search, two sub-processes could have place:

- A similar case is retrieved. So, its associated solution is evaluated to decide if such initial solution will be reuse.

- No similar cases are stored in the memory. Thus, the system will propose at least 1 inventive principle (and no more than 6 between the 40 that exists), that has been successfully used in the past, to solve this specific contradiction in some other domains.

Afterward, the inventive principles which are in reality some standard solutions or strategies to solve problems, must be interpreted to propose a potential solution. Subsequently, both sub-processes converge and the proposed solution is then verified and repaired if necessary in order to obtain a satisfactory result. Finally the new experiences which comprise failure or success, strategies to repair and implement the final solutions, among others particular features, are retained for being reusable in the future and the case memory is updated.
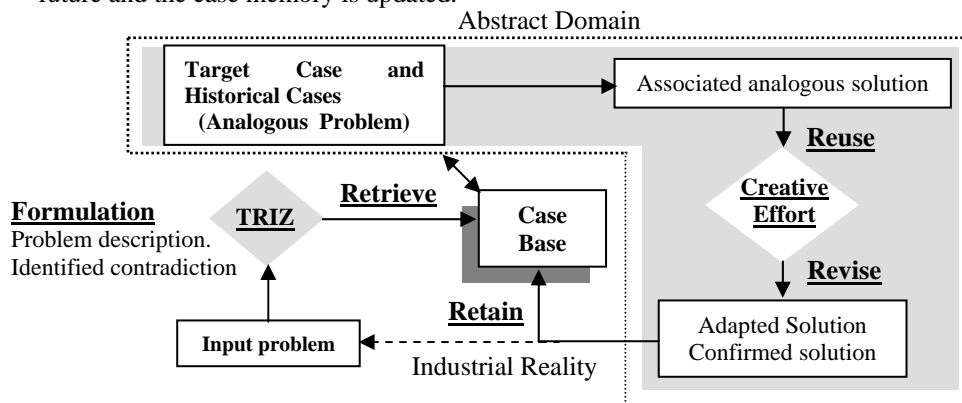

Figure 3: The synergy TRIZ-CBR [11]

Example: to illustrate the use of our tool, a very mere chemical engineering example is presented. The purpose of this example is to demonstrate the interest and principle of operation of our tool. Consequently, the Simulated Moving Bed process (SMB) and its evolution are treated nevertheless this tool can be applied in the same way in an industrial case. The SMB is a chromatographic technique to continuously separate multi components mixture. The starting point is the True Moving Bed (TMB) (figure 4A). The TMB process has to be improved because of its main drawback: circulation of a solid phase. As explained earlier, this drawback is expressed in term of a contradiction: line 33 and column 19 of the matrix. The crossing cell does not give some previous similar case in the memory. Thus, a creative solution has to be formulated with help of the principle in the crossing cell: (1) Segmentation, (13) Inversion, (24) Intermediary. The first principle specifies that the object or process can be fragmented into independent zone. On of the sub-principle of principle 13 is "Make movable parts fixed and fixed parts movable". Having in mind that the circulation of the solid must be reduced, it can be fixed. Consequently if the solid becomes static, we have to perform the inlets and outlets ("fixed parts movable") in a rotating way. Combination of both principles 1 and 13 gives the solution (SMB) (figure 4B).

In its evolution, the SMB process has to be improved because it is only limited to one function: separation. Here again, a contradiction is expressed. But now, the crossing cell gives us a previous case with its associated solution in the memory: make an object perform multiple functions like in reactive distillation. The solution is adapted to our problem to give the Simulated Moving Bed Reactor.
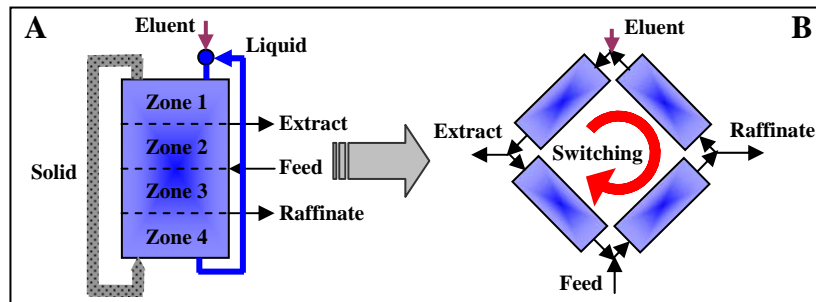
Figure 4: the Simulated Moving Bed Reactor

5. conclusions

The presented model offers a way to transfer the solution from an identified analogous problem to a new target problem, reducing effort and time in solving problems, because this approach combines the TRIZ ability to propose creative solving strategies applicable across-domains, and a framework that closely relates knowledge and action, besides one of the ways to drive the innovation process, consist in reusing knowledge that has been acquired. Another important product of this model is learning, which is in fact an inherent to a CBR system, because a CBR system store in a memory passed experiences for later use and for that reason, an excellent way to share knowledge. This model has been implemented in a computational system which is actually in test at the Industrial Systems Engineering research group from the Laboratory of Chemical Engineering (LGC-PSI).

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