Presentation of a tool for problem solving improvement: application in process 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, CBR.

1 Introduction

The particular vision of TRIZ is based on the history of technological evolution. TRIZ considers innovation like a process which can be controlled and deployed systematically. Paradoxically, this knowledge based approach with transversal domain application, does not have the capacity to memorise, which is fundamental for learning. Consequently, knowledge that has been employed and created while solving inventive problems can not be reused. This drawback has a negative effect on problem solving performance while deploying TRIZ.
On another part, knowledge management has developed the capacity to identify, store and reuse knowledge. This is the core capacity of several knowledge management methodologies, among them is, the Case-Based Reasoning (CBR). The performance of this problem solving tool, lies essentially in its capacity to offer a pragmatic answer for specific domain problems. CBR systems solve a new problem by identifying its similarity to one or several previously solved problems stored in a memory and by adapting their known solutions. Since CBR application is domain specific, CBR cannot consider the solutions that have already been identified in others domains while solving new problems. This characteristic limits the CBR's capacity to propose innovative solutions to a problem. Besides, a shortcoming is revealed when a CBR system faces a problem that had not been solved in the past. If this situation occurs, the memory cannot find a similar problem and consequently, no solution is proposed.
The limits and complementarities observed between TRIZ and CBR are employed to propose a new model. This model presents an approach that combines the technological vision of TRIZ and the ability developed by CBR to memorize and to reuse knowledge. This synergy firstly allows steering the creative effort when facing inventive problems and secondly, to reuse knowledge that had been acquired in past problems. This paper is composed of five parts, the first one presents the CBR methods. In the second, the TRIZ tools and concepts involved in the model are detailed. The model and the tool created on this model will be detailed in part 4. And before to conclude, the capability of this new approach is illustrated by an application in process engineering.

2 CBR cycle

A document titled "Dynamic Memory: A theory of learning in computers and people [Schank, 1982], is the foundation of the CBR approach. This document describes the memory-based approach to reasoning, which means that human memory is dynamic because it is continuously changing according to the new problems or situations (cases) faced.

Consequently, these new experiences which inherently contain some lessons learned in a particular context could be employed to face new ones. The CYRUS system developed in 1983 by Kolodner, was the first computer implementation of many of the schemes exposed in Schank's work.

Cased base reasoning (CBR) is an Artificial intelligence method that involves solving problems based on past solution of similar problems. The general principle applied in CBR is: similar problems have similar solutions. CBR relies on storing solutions as well as problems and adapting these solutions to solve new similar problems. The central notion of this methodology is a case, which corresponds to the problem description, its solution and eventually some comments. Many cases are gathered and stored in a memory, named the case base. Consequently this case base is composed of two spaces as illustrated in figure 1: the problem space and the solution one. For solving a problem with CBR, you have to describe it, then measured the similarity of this input problem (target problem) with problems stored in the case base and retrieved the (or more than one) most similar problem and its solution. Then the target problem is solved, and finally the input problem and its solution form a new case and it is stored in the memory in order to increase its effectiveness for problem solving. These are the general steps of the CBR cycle, detailed in the next part.

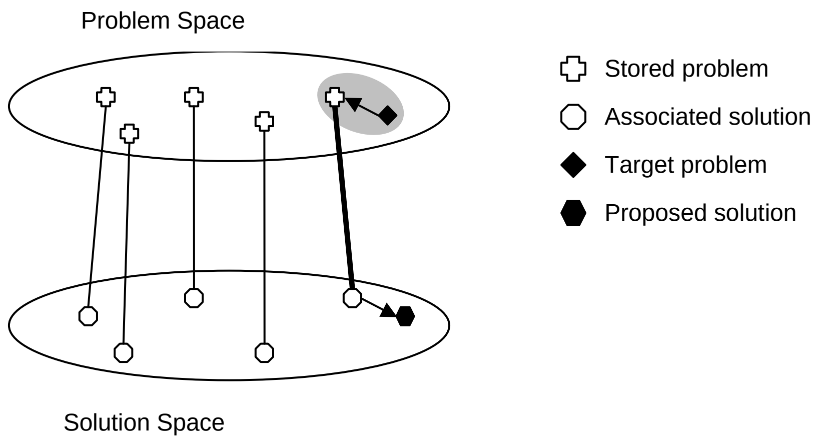

Figure 1: CBR description

The individual steps in the CBR methodology form a cycle: Retrieve Reuse, Revise and Retain [Aamodt, 1994], figure 2. But before to use the CBR cycle, a preliminary important step consists in representing the experiences contained in the cases for reasoning purpose. For the purpose of this article a case is represented as a vector of feature-value pairs, for the problem and solution descriptions. Of course, problems and solutions are described with different numbers of features and different information. After this preliminary step, the CBR cycle can be started:

Retrieve: According to a new target problem, this step of the CBR cycle is the retrieval from the case base, of previous cases that are similar. Here, the central issue is the similarity measurement in order to find the most useful case to solve the target problem. The similarity between two cases is measured by a function which depends on the type of features value: words, numerical values, diagrams, plans….

Reuse: The goal of this step is to propose a solution to the target problem, adapted from the solution(s) of the retrieved case(s). This solution is used as a starting point for the problem resolution. Reusing previous cases solutions can be as trivial as applying the solution without modification (for example when the retrieved case is sufficiently similar). However in the majority of time, there is a gap between the target and similar problems, then the retrieved solution does not exactly correspond to the target problem and it often needs an adaptation.

Revise: The previous adapted solution is used as the starting point for the target problem resolution. Even after the reuse step, the solution perhaps needs some adjustments to fit the target problem. Consequently, the user revises the solution generated in the previous step to resolve the discrepancy between the desired and the adapted solution: by simulation, optimization for example.

Retain: After its solution, the target problem and its associated solution form a new case. If it brings something, the CBR system may learn this new case by its incorporation into the case base. This step extends the cover of space problems, increasing the CBR effectiveness by enlarging experiences retrained.

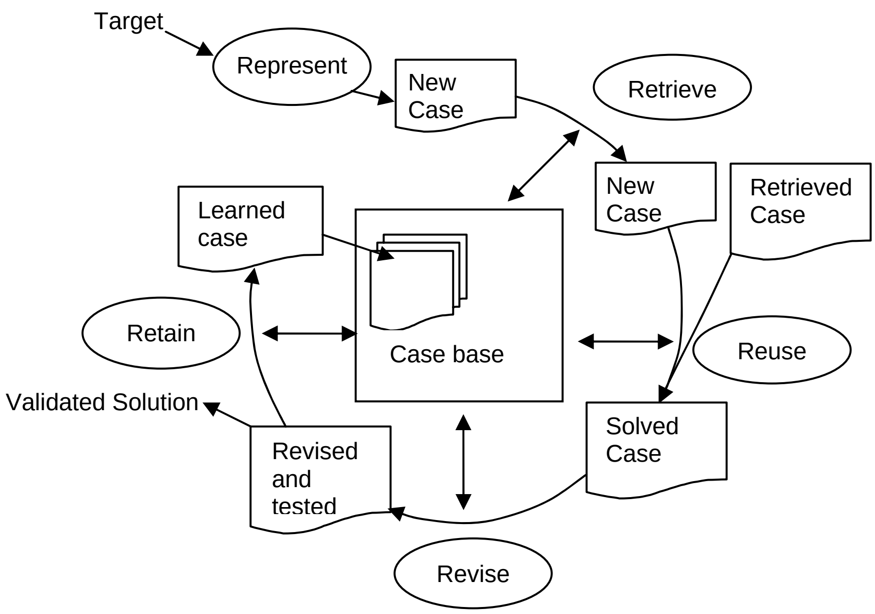

Figure 2: CBR Cycle

The CBR approach is very interesting for complex problems resolution. CBR have advantages like: its facility of use and maintenance … But, CBR is focused on a specific domain then the reasoning in the same technical domain becomes a drawback because with focusing only in a particular domain, solutions which appeared effective in others domains are avoided. And the diversity of domains taken into account often has a positive and favourable impact on the solution quality and innovation. Consequently we must change the approach and try to find a solution with others types of methods like TRIZ for example.

3 TRIZ tools

In this section we do not present TRIZ, because all the members of the TRIZCON congress are aware of this theory [Altshuller, 1984]. We only present the concepts and tools that we use in our model:

Ideal Final Result: the IFR is used to start the reflexion to the problem to solve but also to propose a criterion to choose in a set of possible solutions the best one because each problem can be solved in many different ways.

Contradiction: As we see in CBR we have to formulate the problem with features. Here we choose the contradiction formulation for the problem (not only because others features are added to describe more precisely the problem). The Innovative Situation Questionnaire (ISQ) will be helpful to formalize this contradiction. The 40 principles are also used to describe the solution part of a case.

Of course TRIZ has various advantages for our model: its capacity to stimulate creativity of each person, the fact that it eliminates barrier between industrial domain (more innovative solution), and its reduced time to produce a solution. Nevertheless a drawback appears because each time you face a new problem, you have to redeploy the whole process of resolution which can be time consuming. The synergy proposed in the next part eliminates this drawback by using CBR in order to avoid redeploying the whole TRIZ process resolution. The synergy exploits the main advantages of TRIZ and CBR.

4 The Model

Because of the complementarities of the two approaches (detailed in [Cortes Robles, 2006]), it is interesting to couple both of them in order to propose a tool to support and accelerate problem solving. This tool must offer systematically a way of solution for each new problem encountered. In this synergy, TRIZ brings the initial structure, i.e. the contradiction matrix, to produce a support to index and store cases and to propose a solution if no similar case is found. The contradiction Matrix has two roles: its initial one coupled with the case base one. On the other hand, CBR brings techniques to accelerate problem research and comparison with other ones solved before.

In traditional CBR, the central notion is a case composed of three elements: problem, solution and some comments;

$$Case(PB, Sol(PB), Co)$$

In the synergy a case is represented in the same way. The problem must be formulated by its contradiction, because the contradiction matrix is the support of the case base. Consequently the two first features are the contradiction parameters. These parameters are also useful to index the case base and consequently accelerate the research of similar problems during retrieval. As explained before, additional features are added: the unit operation where the system is located, the type of objectives, the goal to reach, the resources identified in the system…

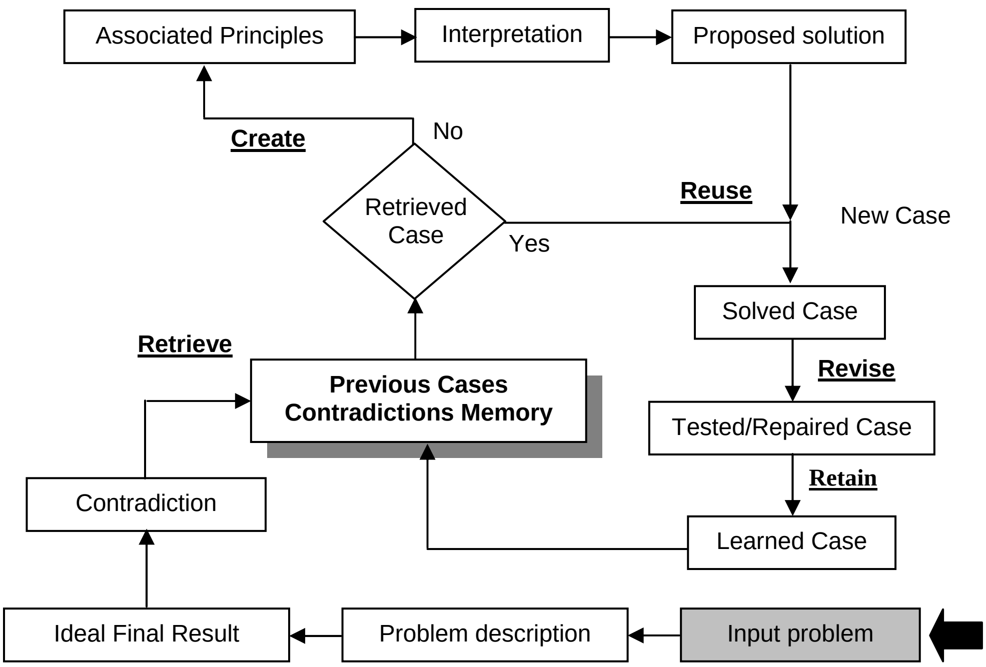

Figure 3: Model with TRIZ-CBR coupling

After the case representation, the resolution process proposed in the synergy can start, figure 3. The resolution process starts with the step of identification of the target problem: problem description, ideal final result, contradiction. After case representation, the retrieval step finds the most similar case(s) to the target problem.
From the retrieval step, the process detailed on figure 3 considers two possibilities:

- A similar case is found in the case base. Then its associated solution is proposed and adapted to the target problem.
- Not enough similar case or worst, no similar one has been identified in the previous experiences stored. Then, the matrix finds its initial role and proposes the principles associated to the contradiction to reduce the solution space.

5 Example in Process Engineering

The goal of this part is to highlight the possibilities of the synergy TRIZ-CBR. Chromatographic separations are unit operation techniques to continuously separate a multi component mixture. One of the possible technological starting points of this unit separation is the True Moving Bed (TMB), for which a simplified version is illustrated in figure 4. For the TMB separation technique, the component mixture is sent in a column where the liquid and solid phases flow in counter current directions. The liquid outlet of zone 4 is recycled to the zone 1 inlet, and conversely for the solid: the zone 1 outlet is recycled to the inlet of zone 4. Moreover this apparatus has one feed (with the mixture to separate) and two outlets to withdraw products: extract (rich in the component the more retained, preferentially in the solid phase) and raffinate (rich in the less retained component, preferentially in the liquid phase). The principle disadvantage of this technique is the flow of the solid phase, which is a complex task.
With the help of TRIZ tools (like Innovative Situation Questionnaire), the first step is to identify the technical contradiction. In this case, the contradiction can be formulated in the following way:
Improved parameter: the flow of the solid phase implies a difficulty of use, consequently the parameter 33, 'Convenience of use' is chosen.

Damaged parameter: it is the parameter 19, 'Energy spent by a moving object'.

The crossing of line 33 and column 19 of the matrix gives the followings principles: 1 Segmentation, 13 Inverse, 24 Intermediary. The first principle specifies that the object or process can be fragmented into independent zone. Consequently the first idea is to divide the system in 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 in order to simulate fluid flows. Combination of both principles 1 and 13 gives the solution (SMB).

As it is clearly explained by [Pais, 1998], the counter-current flow of fluid and solid is simulated. The absorbent bed is divided into a number of fixed beds. The inlet and outlet lines move simultaneously one fixed bed at fixed time intervals towards the liquid direction (figure 5). This is the technique of the Simulated Moving Bed.

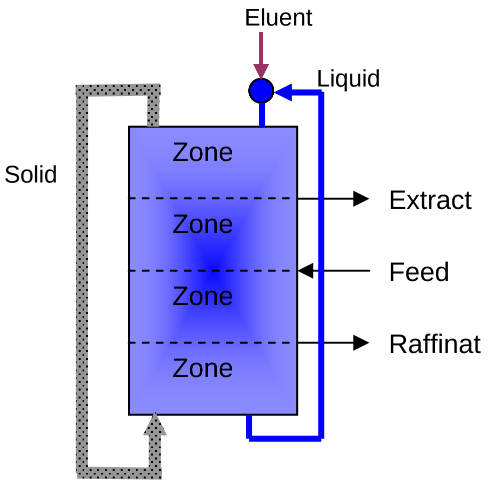

Figure 4: TMB

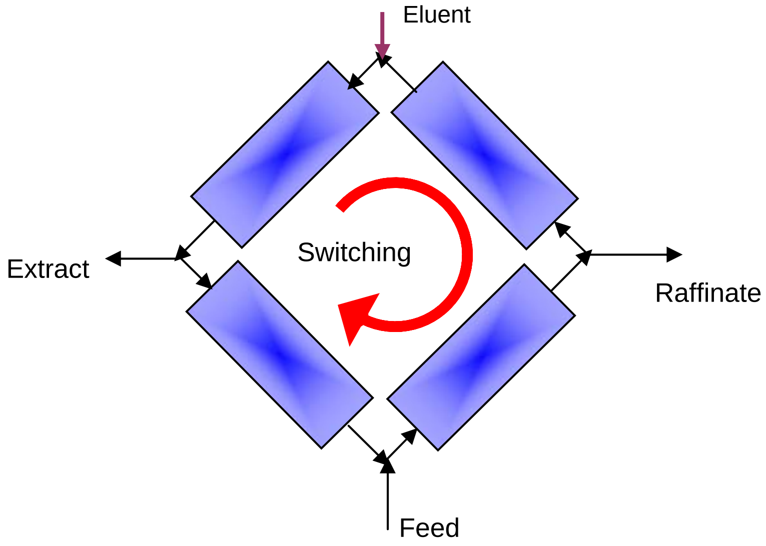

Figure 5: SMB

6 Conclusion

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 inherent to a CBR system, because a CBR system store in a memory past experiences for later use and for that reason, an excellent way to share knowledge. This model has been implemented in a computational system.

A future work is devoted to solve problems represented by several contradictions, because complex problems are often represented by simultaneous contradictions. But our tool can solve only one contradiction and consequently we must consider different cases for contradictions related to the same problem.

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