INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED'07
28 - 31 AUGUST 2007, CITE DES SCIENCES ET DE L'INDUSTRIE, PARIS, FRANCE

IMPROVING THE RELEVANCE OF R&D'S PROBLEM SOLVING ACTIVITIES IN INVENTIVE DESIGN CONTEXT

Denis Cavallucci[1], Thomas Eltzer[1]
[1]INSA Strasbourg – Graduate School of Science and Technology – Design Engineering Laboratory (LgéCo).

ABSTRACT
Research and Development Activities (RDA) in enterprises rely on a long historical set of experiences gained through practice, developed methods and continuous improvement. Such activities need to evolve permanently to stay abreast of the global industrial situation. The evolution of R&D is conditioned by, amongst others, the need to justify its efficiency, since its activities are often seen as a source of unfruitful expense. This is doubly true in the context of invention, where results are expected to be simultaneously innovative and cost effective. In this article we propose to demonstrate how Inventive Design techniques can greatly assist strategic decision-making within R&D as we move into the Innovation Age. The proposed approach consists firstly of observing and modelling problems of knowledge of competing technologies using contradiction formalism. This is done using data available in patents relevant to the field and know-how of domain experts. Next, the weighing of parameters involved in problems definition assist the identification of key problems to be solved for maximum impact on the studied system. Finally, the previous steps permit tried and tested innovation techniques to be applied to maximum effect on the problems having the greatest strategic impact. A case study of an industrial application in a worldwide bed frame manufacturer is presented.

Keywords: TRIZ, Inventive Design, Intellectual Property, Knowledge Representation, Innovation, R&D Activities.

1 INTRODUCTION

1.1 Knowledge importance in problem definition
The crucial role held by knowledge in R&D's efficiency has often been described [1]. A review of published work on this subject reveals substantial contributions from both management and human sciences. In the sciences of engineering, researchers in Information Systems have long underlined the difficulties of organizing the flow of Knowledge [2]. Despite these numerous contributions and intensive research findings, Knowledge management (KM) is qualified by [3] as having "…a mediocre success record in companies." The arguments brought forward by the authors for justifying their assertion are that the problems of transmission from person to person and the difficulties of harmonization of aims between management and engineers mean that efficient organizational learning has yet to be achieved.
In a previous paper, we have already expressed the need to link knowledge representation and problem solving logic [4]. Our hypothesis was that the use of the contradiction axiom (as developed in the theory of Inventive Problem Solving) will partially address the issues of complexity reduction, problem representation and problem management, thereby orienting and assisting problem resolution stages. In the next section, we will focus in particular on Knowledge extraction from patent texts.

1.2 Patents as an important element of Knowledge residence
Patents have always been seen as an important knowledge source and used accordingly [5]. Nowadays they are generally exploited via dedicated (paying) web portals. These allow the visualisation of various data (Inventor, assignee, title, keywords, claims …) through specific representations (Charts, bar, pie, clouds …). This is useful for observing competitor's inventive activities and attempting to establish the

trends of evolution of a specific technical object, but patent content is much richer. As an example, kitamura in [6] has exposed the use of "patent map" as a means of understanding a specific domain.
Several methods are proposed in the literature of patent usage for knowledge extraction and representation. Some of them, [7][8][9] propose to cluster information for presenting the documents to users querying a specific topic of interest. Companies like Micropatent® and Matheo®[1] are proposing to draw trees of prior art in order to keep track of the inventive findings proposed for a specific subject. In [10] the author is going further in analysing a patent's text, proposing an algorithm combining various clustering techniques to find relationship between assignees. Furthermore a 2D graphic shows the overall relationship among patents as a visual network, aiming at extracting technological trends and identifying promising paths for new product development. Despite the interesting aspect of providing R&D deciders with hypotheses of product evolution through a better monitoring of a specific situation, no significant measurement of efficiency to target a specific goal is given. This brings forward the problem of comparing the efficiency of expert judgments (and intuition) and such methodological approaches.

1.3 Inventive problem formulation

The Theory of Inventive Problem Solving (TRIZ from its Russian acronym) includes a detailed decomposition of Inventive Problem (IP) formulation. Observed through the framework of ARIZ[2], a problem is decomposed and reformulated until its structure offers at least one possibility of resolution which makes effective use of identified resources. But the difficulty of identifying the right problem to be solved has not undergone numerous studies by TRIZ founders and researchers of these early times (1946-1985) [11]. Nowadays, researchers from various origins and scientific fields have attempted to address this problem. Some of them have understood the richness of Patent text content and the key role its exploitation could play in framing the knowledge involved in problem formulation and resolution stages.
For instance, in [12][13], the authors propose a method to analyse patent text inspired by an existing software product: Knowledgist, nowadays integrated in Goldfire InnovatorTM[3]. This major step in the use of knowledge extracted from Patent text nevertheless presents a major limitation: it expresses the information as a function instead of stating the problem through contradiction formalism, partially loosing the richness of what TRIZ proposes within its fundamental axiom concerning problem formulation and understanding.
A model using patent text mining and analysis which expresses the findings in contradiction format has been proposed in [14] [15]. The authors are proposing a promising concept, the use of domain ontology and thesaurus construction for allocating words on specific domain to ease the comprehension and use of the patent. This partially addresses the problem of associating meaning to words in a specific context, but does not solve the problem of completing the contradiction model for an eventual use in ARIZ deployment.
Another major contribution is proposed in [16] where the authors have chosen to process the patent using text mining procedures resulting in a more accurate presentation of results (using graphs). The base of the increase in accuracy is obtained through tuning the processing by comparison between Title, Abstract, Text and Claims. The result significantly speeds up the understanding of a patent content, but the process still doesn't reveal contradictions.

2 FORM CORPORATE KNOW-HOW TO ORGANIZED KNOWLEDGE

2.1 Questioning experts

A well identified problematic to initiate a problem solving process is challenged amongst others by knowledge gathering. If we consider as prototypes of knowledge expert's know-how, a first step consist in questioning them appropriately for an exhaustive extraction. We have observed in such situation that a specific treated subject was defined differently by each expert. These differences are mainly due to

---

[1] Micropatent and Matheo are registered mark, their description can be found at:
http://www.micropatent.com/
http://www.matheo-software.com/

[2] ARIZ is a Russian acronym standing for Algorithm of Inventive Problem Solving. It consists of a dynamic system of 39 steps offering a frame for problem formulation, knowledge re-organization and structures the use of TRIZ knowledge bases and tools' use for problem resolution and solutions management.

[3] Goldfire Innovator is a trademark where some overall presentation can be found at: http://www.invention-machine.com/prodserv/GFIN.cfm

individual viewpoints and expertise but as a consequence, difficulties to stabilize a commonly shared model of knowledge arise.
In figure 1, we propose a model of questioning whose objectives are to constantly integrate a newcomer's viewpoint (a new expertise shared). This framework is based on wiki-like technologies and appropriately fits to the need of a common validation of a shared model of knowledge.

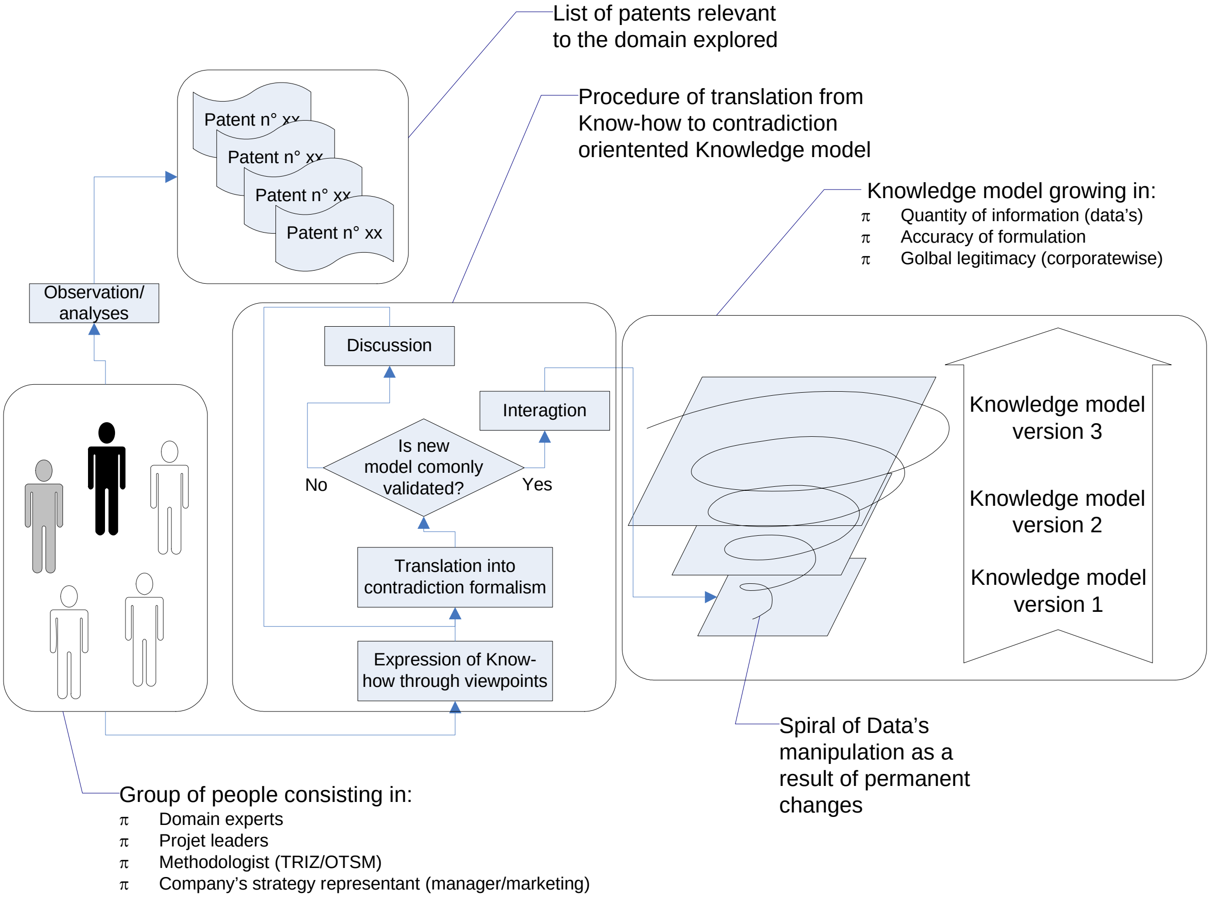


Figure 1: Schematic illustration of Data's gathering and manipulation

2.2 Engineering domain definition

A specific domain of knowledge can be defined according to [17]. In industrial situation, R&D engineers and deciders commonly agreed in pointing the following elements as being the sources of knowledge to define a domain:

- Patents: Mostly those granted to the known competitors of a given technology.
- Experts: People involved mostly for long in a specific area and carrying a consistent understanding and mastering of a given technology.

As we already have mentioned in section 1, patents are extremely useful to observe and survey knowledge evolution in a given domain. In this paper, we would nevertheless focus on expert's questioning procedures since other ongoing research work is focusing on semantically analyze patent text for assisted extraction of information useful for problem formulation and domain mapping. In addition, we have observed that there is a significant overlapping between experts tacit and explicit knowledge and patent content since companies are often using them for competitor's survey and technology analysis.

Before going further, the following terms are given to define a specific engineering domain:

- An engineering domain: defines a sum of knowledge associated to a specific category of Technical Systems performing a similar useful function.
- An engineering sector: a subdivision of an engineering domain constituted of a relevant technical difference.
- A specific technology: Component technologies represented in an engineering sector.

2.3 Structuring data's for situation mapping

Brought from the Inventive Problem Solving Theory (TRIZ), contradiction formalism is then used for structuring the obtained data's from the previous stage. Our objective at this stage is not to clearly define each element using a detailed description (units, values) but to semantically express the problem in a simple a standard form. The model of problem formulation we propose is based on a dialectical model of contradiction and features three different elements:

- Elements: Mostly nouns or groups of nouns employed as subjects of a given sentence.
- Parameters: Complements (of a noun or a subject) qualifying subjects.
- Values: Mostly expressed using adjectives associated to complements.

Then, the following scheme (figure 2) is used for expressing a specific engineering knowledge model extracted from patent texts and their interpretation by domain experts:

$TC_{n.m}$	Active Parameter AP_n	
	Va	Vā
Evaluating Parameter EP1	☺	☹
Evaluating Parameter EP3	☹	☺

Figure 2: Generic contradiction Table

Here we would like to underline the necessity to define an opposition of states (values) and use the concept of antinomy to rise the uncovering of a complete contradiction definition. The final objective is to possess a series of knowledge models, dialectically expressed using contradiction formalism. After uncovering and co-validating all dialectical models of contradictions, a checking phase consist in observing if within all contradictions, every fundamental aspects of a given engineering domain has been cited. As long as an important aspect of a specific domain does not appear in the list of contradictions, there is a necessity to reveal a new contradiction and list it. The overall process of co-validation of the contradiction list can use the same process as within a specific one as mentioned in §2.1.

2.4 Linking a technology to its set of forthcoming contradictions

According to TRIZ's first and second axiom [18], a contradiction must be observed as a model of problem that a technical system is facing with to evolve in accordance with a law [19]. If a given company wants to rank (prioritize) contradictions to be solved along a specific path of evolution, then rise the need to link technologies, contradictions and company's objectives.

A contradiction is composed of one Active Parameter (AP) and at least two Evaluating Parameters (EP). When Evaluating parameters are superior to two, we can employ the term poly-contradiction (as shown in figure 3) [20] to define this specificity.

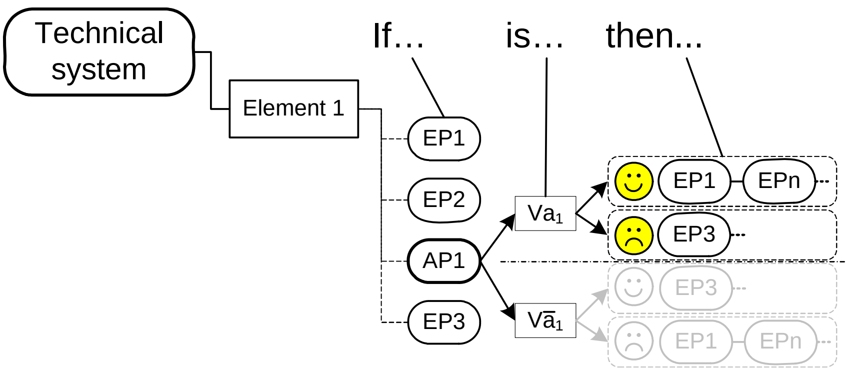


Figure 3: ENV diagram for polycontradiction's representation

As it has been already defined in [21], an Evaluating Parameter represents an evolution in a desired direction. The concept of having inventively solved a contradiction within TRIZ framework signifies that both contradictory requirements are reached without compromise. Therefore it is possible to individually weight the importance of each EP according to company's strategy and objectives. As a result, each EP possessing a weight will add more weight to each contradiction they are involved in. A chart presenting all contradictions with their respective weight can then be established and analyzed to initiate Inventive Problem Solving Activities.

3 CONDUCTING INVENTIVE PROBLEM SOLVING ACTIVITIES

3.1 Initiating Inventive Problem Solving Activities

An important aspect drawn in section 2 is that a dynamic model of Knowledge has been built. By definition, this dynamicity offers to actors of the company the possibility to forecast the impact of an IPSA's result on the problematic situation. It also assists the head of an R&D department to appropriately launch an IPSA activity due to a given objective. This will give the opportunity for R&D teams to build alternative scenarios:

- For instance, in a context of cost reduction the engineers involved in weighting EPs can allocate a different weight to Eps influencing strongly costs. As a result, contradictions having a significant impact on costs will be targeted among others.
- Another use could lead R&D deciders to challenge the novelty of a given IPSA, then, the weighing of each EP's may differ and bring forward those who are aiming at placing a given technology ahead in front of a competing area.
- A company might also pursue both objectives: For instance if they want to have both a short term R&D effort with immediate ROI expectations and a medium (or long) term R&D investment in their strategy. In such cases two alternatives scenarios should be analysed and conducted in terms of IPSA.

The schematic representation figure 4 illustrates the generic process of using inputs of a given situation (competing arena: competitors, technologies and contradictions associated to them) (1) to lead decisions. Based on the result of a knowledge gathering stage, a list of contradictions identified as true for a given technology can be ranked taking into account a given scenario's variables. The display of ranked contradictions (3) associated to scenarios (4) is therefore a useful assistance to R&D decisions makers taking into consideration strategic and technical data's (2).

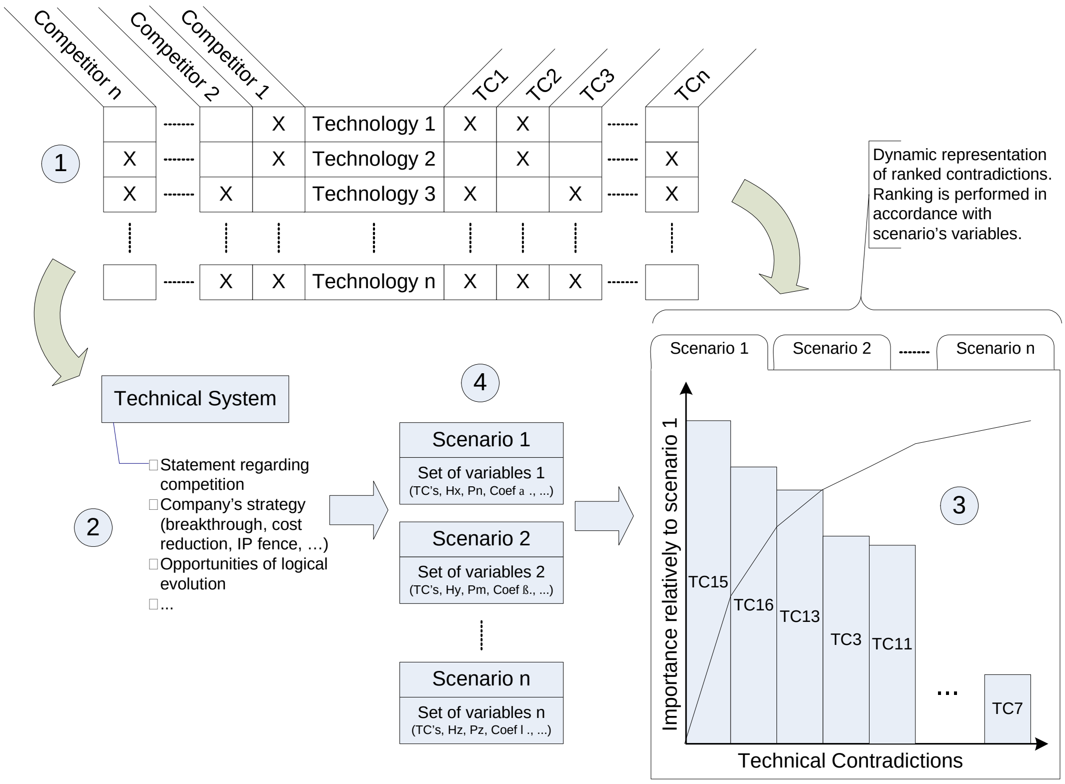


Figure 4: Ranked contradiction based on multiple scenarios

3.2 The use of TRIZ's problem solving heuristics

Once a set of contradictions have been pointed, we have learned from TRIZ that several elements of its body of knowledge can be used to inventively resolve the conflicting requirements without compromises. As a proposal to guide engineers in charge of IPSA and their use of TRIZ methods and tools, we have drawn a scheme (figure 5) illustrating the links and possibilities to treat individually contradictions.

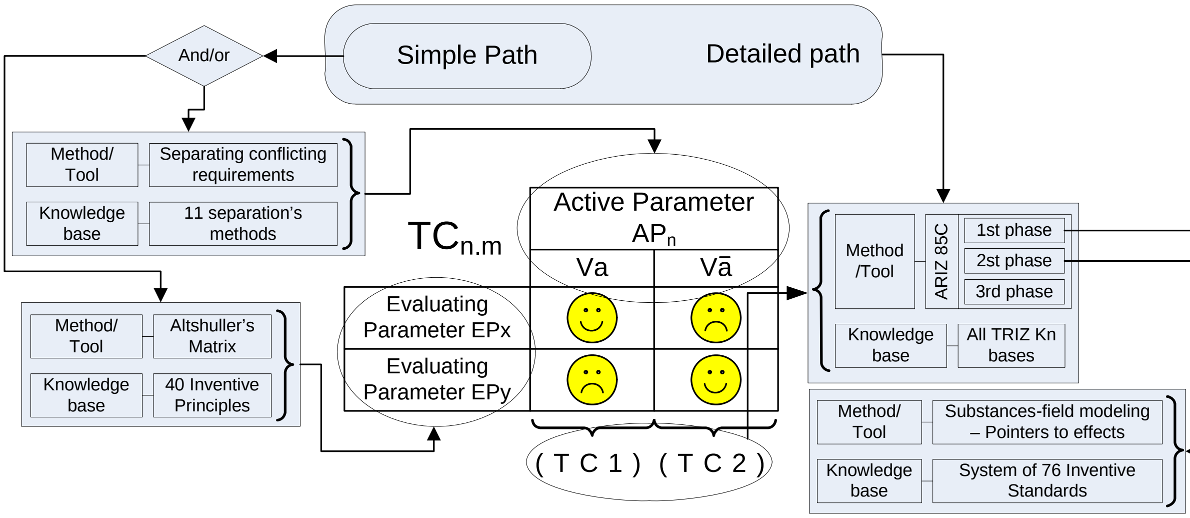


Figure 5: Flowchart of TRIZ's body of Knowledge use for addressing a contradiction

This flowchart can be used to guide engineers in their use of TRIZ elements when a given technical contradiction has been targeted. As an example, if they have a significant amount of time to dedicate to problem solving, they may use the "detailed path" witch will lead them to use either ARIZ 85C for solving "non-standards problems" or "Substance-field analysis» and "system of Inventive Standards" for solving "standard" problems.

3.3 Linking Inventive Solution Concepts with network of problems

As a result of an IPSA, we have a set of Inventive Solution Concepts (ISC) solving the initially expressed contradiction. The feasibility of each ISC and its characteristics will lead to impact and provoke changes in the initial statement of problems. Not only problems that have been initially addressed will be solved, depending on the typology of a given solution, some additional problems might have also been solved. In addition, new problems in the implementation of new solutions can also arise. Therefore, a permanent link should be established between Problems and Solution Concepts to update the statement of problems and consider that contradictions are the levers for initiating R&D activities.

4 CASE EXAMPLE: ELECTRICALLY POWERED BED

4.1 Dunlopillo's situation

In this section we have summarized the key points of our method through the use of a case study conducted in cooperation with Dunlopillo's R&D department. The initial situation was presented to us the following way: an electrically powered bed is composed of a complex architecture to assume its main useful function (figure 7&8). This has led in the past engineers to create mechanical motions to fit both consumer's expectations and ergonom's definition of body segmentation to reach a maximum comfort. Throughout the system's evolution, the electrically powered bed frame has been optimized and has integrated latest technological developments (new materials, advances in electronics, in control units…). The actual statement is that concerning motion, components' quantity and assembling, in the individual and global optimization of parts and functions, everything has been optimized and the product in its actual architecture has been minimized in terms of costs.

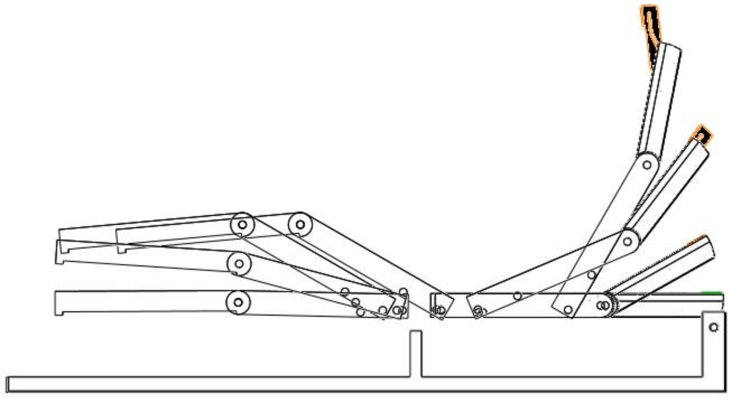


Figure 7: Schematic illustration of a classical bed frame

The marketing department has decided to address a new market (young adults) since this sector was a challenge for most of competitors to conquer. The problem arising is that this segment does not have the same budget to acquire their product. The costs to produce and to propose an electrically powered bed should be reduced by 40% to become reachable by young people's budget.
Our cooperation started from this objective and was aiming at developing a new concept of bed frame architecture that would significantly reduce its overall costs (40% reduction was the real goal).

4.2 Stating on the system's maturity

A fist step within the understanding of the exact systemic boundaries of our Bed frame provided us a description of its main components and Main Useful Function (figure 8).

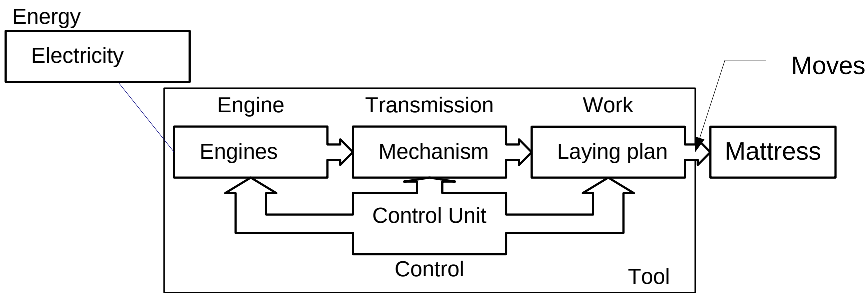


Figure 8: Bed frame's structure according to Law1

As the first TRIZ axiom indicates, technical systems evolve in accordance with objective laws. It is therefore important to analyse and understand its actual maturity and formulate hypothesis of evolution in accordance with the laws. In our case, optimization of actual bed frame's technology has reached a maximum (Law2). Nevertheless to be in harmony with the need to perfectly fit human body's motion (Law3), it should evolve towards more segments than its actual state. An ideal situation would be to reach 20 segments instead of 5 to 6 actually depending on bed frame versions. This static analysis is consolidated by Law8 which indicated that technical systems evolve towards a higher level of dynamicity.

4.2 Converging to key problems weighing contradictions

A sum of 17 contradictions has been synthesized during expert's questioning and analyses of competitor's patents. These contradictions have been weighed to address in priority those impacting the most bed frame's costs (see table 1 and figure 4). In our case, even if two contradictions have emerged as significant, TC1.5 was identified to be solved since its internal components (Evaluating parameters constituting the contradiction) were directly linked to company's strategy for addressing our challenge (amount of laying plans, system's complexity, ability to match body's curve).

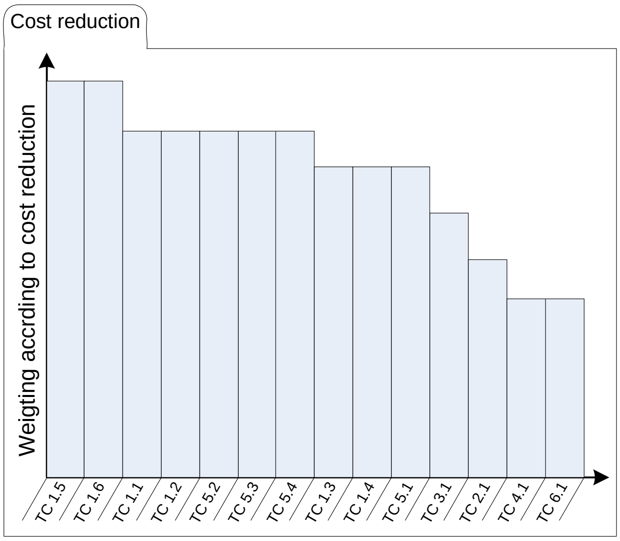
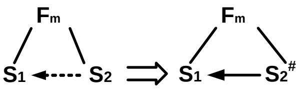


Table 1: Weighted and ranked contradictions according to cost reduction's scenario

4.3 From problem formulation to inventive solution concepts

Once TC1.5 is becoming the targeted contradiction to be solved, TRIZ tools and methods can frame the solving process. According to figure 5, a detailed path has been chosen for solving the contradiction and at the end of the first phase of ARIZ85C, it is proposed to employ substance-field modelling to access to an appropriate inventive standard. The characteristics of our situation particularly fit class 2 and standard 2.2.2 seems appropriate in our case. It has then been interpreted (figure 9b) and the result of this interpretation provided us a direction for building a solution concept.



Where: *S_1 is the mattress*
S_2 is the lying surface
$S_2^{\#}$ is a segmented lying surface

St. 2.2.2: S2 segmentation	Interpreted Solution Concept
The effectiveness of a Su-field can be increased by rising the degree of segmentation of the substance employed as an instrument (S_2) interacting with the object (S_1).	The lying surface should be divided into (ideally 20) smaller segments. These segments should be simply controlled (individually or globally) by a minimum of means.

Figure 9: a) Inventive Standards 2.2.2 with bed frame's attributes b) Table of standards formulation and designer's interpretation

4.4 From Inventive Solution Concept to technical implementation

The interpreted solution presented previously has been studied and engineered in order to fit all requirements of the previous design. The objective was not to degrade certain aspects of the previous solution in order to preserve the inventive level of the new solution. The calculation of both kinematics motion and overall cost estimation of the new concept shows important improvements in several directions:

- First, we've improved the amount of lying surfaces from 6 to 11. Despite that each plan is less efficiently controlled, the capacity the new solution develops allows a possible match to body curves due to the angle of contact between two plans.
- Second, the overall costs are significantly reduced since the initial complex mechanism is replaced by simply two motors and their respective reductors (with as it was before, a command unit).
- Finally, volume and weight are also reduced since the simplicity of the new mechanism is more compact and lighter.

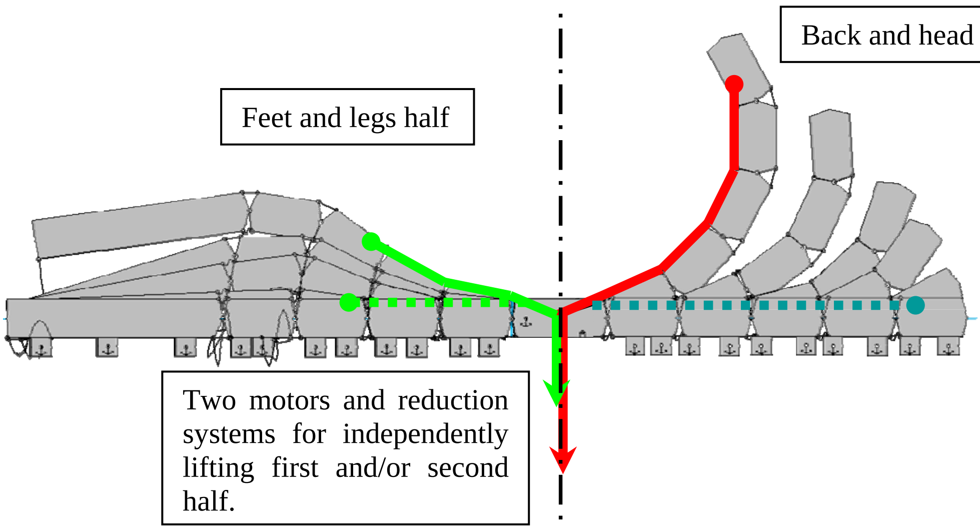


Figure 4: Solution Concept resulting from Inventive Standard 2.2.2's interpretation

As a result of the design process, a new bed frame has been prototyped and presented to marketing and management departments. This consists of a two separated motor bending in a limited amount of rotations a customized vertebrae where each two surfaces in contact provide a specific angle and as a result along a series of contacts, a shape. The solution is restricted to two motors since it was stated that two independent controls (one for legs, one for upper part of the body) was sufficient. Further, several patent applications have been initiated since a first attempt to state on the novelty of such concept did not show any previous granted patent in their industrial area.

5 DISCUSSIONS

5.1 Setting-up means for measuring practices evolution

The industrial world is largely driven by financial performance indicators and evolving successful strategies to improve them. In [22], the authors have pointed out that there are well understood ways to calculate a firm's return on investment or ROI but emphasize the fact that the financial model is somehow disconnected from the product development process when evaluating how much industrial design contributes to corporate performance.

In [23], R&D's performance is once more in question, mostly in stating what its exact boundaries might be within the overall structure of a company. The adopted definition in our approach comes from [24] where R&D is defined as: "(any activities that) contribute to the introduction of technologically new or improved products or processes in the firm concerned."

As we have previously stated, to exert a positive influence on R&D performance in an inventive context, we postulate that IPSA should be carefully targeted. If we focus on each type of RDA, a part of their description consists of separating their findings into three categories (Long, Medium and Short Term) [25]. Another input, useful for understanding RDA, is to add a qualifier to their results. As it can be summarized from [26] each Activity (An) depending on R&D investments can be categorized into three different results typologies:

- Successful (Ai): qualified by both a positive ROI (obtained after cost estimation) and an ongoing activity in manufacturing playing a role in future product evolution (or birth).
- Capitalized Knowledge (Ac): for qualifying any activity leading to the understanding of a previously non-mastered situation. The results are a growth in the understanding of a specific domain useful for future choices but not leading to any developments in manufacturing.
- Dead-end (Ad): qualifying any activity leading to a negative result which will be of no future use to the company. Such activities are usually stopped as soon as possible since their costs negatively affect the return on R&D investments [27].

5.2 Objectives for R&D evolution

At this point, it is important to underline that our intention is not to establish an R&D metric as it can be found in [28], but to understand the impact of an IPSA on R&D.

We have drawn the hypothesis that R&D effectiveness within an inventive context has been positively affected if we observe an evolution of its activities as such:

$$\sum A_{i \wedge c \wedge d\,(t2)} = \sum A_{i \wedge c \wedge d\,(t1)}$$

Let's assume that each typology of RDA is noted:

Ai ; Ac ; Ad and E is their efficiency index
We want to be able to observe:

$$E_{(t1)} < E_{(t2)}$$

where t1 and t2 represent two distant time of observation; thus:

$$\forall A_{i \vee c \vee d\,(t1)}; \forall A_{i \vee c \vee d\,(t2)};$$

If we draw the hypothesis that the overall activity potential of a group of engineers is constant within t1 and t2, we are aiming to observe one of the following situations:

$$(\sum_{t2} Ai - \sum_{t1} Ai) > 0$$

$$(\sum_{t2} Ac - \sum_{t1} Ac) \leq 0 \wedge \geq 0$$

$$(\sum_{t2} Ad - \sum_{t1} Ad) < 0$$

If such an observation can be validated by a measurement of quantity and typology of activities, we can draw the hypothesis that a mastered Inventive Design practice is impacting positively on the evolution of inventive R&D.
Based on this assumption the evolution of Ais in t2 becomes a crucial target. An important part of failures during RDA launching stage are due to the failure to select appropriate inventive subjects. This "weak link" in the design process has often been pointed by researchers in engineering Design. In [29] problem finding is presented as "…a missing dimension of the design/problem-solving literature"; while much earlier, Wertheimer in [30] has clearly pointed that "the function of thinking is not just solving an actual problem, but discovering, envisaging, going into deeper questions.". It is now evident that correctly posing the problem contributes to creative problem solving, and is inherently a cognitive activity [31]. In this contribution, we postulate that to evolve, RDA will need to adopt robust problem formulation and evaluation such that resource allocation can be based on informed decisions.

6 CONCLUSIONS

It is acknowledged around the world that one of the most difficult issues facing today's organizations concerns the substantial leaps required to effectively manage innovation. Among other published work, some suggest that a complete rethinking of innovation is required [32]. The proposed methodology not only brought clear inventive results, it also gave the R&D manager confidence when choosing which activities to financially support and brought him concrete arguments to defend his choices. This helped him to switch from intuitive decisions regarding innovation (mostly built upon awareness of customer expectation and studying competitor's activities and evolution) to a targeted problem solving strategy.
The lack of automated text mining tools for directly extracting contradictions from problem statements, particularly in patents, is currently a limiting factor in full exploitation of the proposed technique. The mass of knowledge available in patents remains largely unexploited due to the shear quantity. Automated contradiction extraction would permit significant numbers of patents to be analysed and links made between solutions and problems in completely different industries. This would open new doors for inventiveness where many of the best results come from cross-fertilisation of knowledge or concepts from other industries.

REFERENCES

[1] Nelson R., (1982) "The Role of Knowledge in R&D Efficiency", Quarterly Journal of Economics, Vol. 97, No. 3, august, pp. 453-470.

[2] Schuppel, J., Muller-Stewens, G., & Gomez, P. (1998). The knowledge spiral. In G. von Krogh

& J. Roos & D. Kleine (Eds.), Knowing in firms (pp. 223-239). London: Sage.
[3] Rouach D., Poivey Y., (2000) "Nestlé: Interaction of R&D and Intelligence Management", in Managing Global Innovation, Boutellier, Gassmann & von Zedtwitz (eds.), Berlin, New York, Tokyo: Springer, p. 274-286.
[4] Cavallucci, D. and Eltzer, T. (2006) ‘Parameter Network as a mean for Driving Problem Solving Process’, Int. J. Computer Application Technology, (in progress).
[5] Sheremetyeva S., Nirenburg S., (1996) “Knowledge elicitation for authoring patent claims” IEEE Computer, 57–63.
[6] Kitamura Y., Kashiwase M., Fuse M., Mizoguch R., (2004) “Deployment of an Ontological Framework of Functional Design Knowledge”, Advanced Engineering Informatics, Vol. 18, Issue 2, pp. 115-127.
[7] Kaji, H., Morimoto Y., Aizono T., Yamasaki N., (1999) “Navigation in an Association Thesaurus Automatically Generated from a Corpus”, Proceedings of the Sixteenth Joint Conference on Artificial Intelligence-IJCAI99 Workshop IRF-3: Text Mining: Foundations, Techniques, and Applications.
[8] Tsuda H., (1999) “WIND: Hyper Keyword Index as a Web Document Directory”, Proceedings of the Sixteenth Joint Conference on Artificial Intelligence-IJCAI99 Workshop IRF-3: Text Mining: Foundations, Techniques, and Applications.
[9] Muller A., Hamp B., (1999) “The Information Traveler - A Graphical Browser for Multi-Dimensional Information Spaces”, Proceedings of the Sixteenth Joint Conference on Artificial Intelligence-IJCAI99 Workshop IRF-3: Text Mining: Foundations, Techniques, and Applications.
[10] Zhiqiang L., (2006) “Text Mining Applied to Patent Analysis and an Empirical Study”, Birmingham, United Kingdom, September 10 - 12, EuroMOT 2006 Second European Conference on Management of Technology.
[11] Cavallucci, D. Khomenko, N. (2007) ‘From TRIZ to OTSM-TRIZ: Addressing complexity challenges in inventive design’, Int. J. Product Development, Vol. (accepted - forthcoming in 2007).
[12] Möhrle M., Walter L., Geritz A., Muller S., (2005) “Patent-based inventor profiles as a basis for human resource decisions in research and development”,
[13] Möhrle M., Geritz A., (2004) “Developing acquisition strategies based on patent maps”, 13th International Conference for the International Association of Management of Technology (IAMOT), April 3-7, Washington.
[14] Loh Han Tong, He Cong, Shen Lixiang, “Automatic classification of patent documents for TRIZ users”,
[15] Von-Wun Soo, Szu-Yin Li, Shih-Yao Yang, Shih-Neng Lin, Shian-Luen Cheng, “A cooperative multi-agent platform for invention based on patent document analysis and ontology”, Expert Systems with Applications, Volume 31, Issue 4, November 2006, Pages 766-775.
[16] Cascini G., Rissone P., (2003) “PAT-Analyzer: a tool to speed-up patent analyses with a TRIZ perspective”, European TRIZ association’s conference TRIZ Future, Nov 12-14, Aachern.
[17] Jie B., Vasant H., (2004) “Collaborative Ontology Building with Wiki@nt, - A multi-agent based ontology building environment”, Third International Workshop on Evaluation of Ontology Building Tools. Hiroshima.
[18] Altshuller G.S., (1986) “To Find an Idea: Introduction into the Theory of Inventive Problem Solving”, Nauka, Novosibirsk (in Russian).
[19] Cavallucci D., Weil R., (2001) “Integrating Altshuller's Development Laws for Technical Systems into the Design Process”, Annals of the CIRP, 50, 1 (2001) pp 115-120.
[20] Cavallucci D., Khomenko N., Morel C., (2005) “Towards inventive design through management of contradictions”, International CIRP Design Seminar, 22 - 26 May, Shanghai, China.
[21] Khomenko N., De Guio R., and Cavallucci D., (2005) ‘Enhancing ECN's abilities using OTSM-TRIZ’, IJCE, in progress.
[22] Hertenstein, J.H. and Platt, M.B. (2001). Creative Accounting? Wanted for New Product Development. Advances in Management Accounting 10: 29–75.
[23] Pisano, Gary P. (1990), “The R&D boundaries of the firm: An empirical analysis,” Administrative Science Quarterly, 35/1: 153-176.

[24] European Comission, (1996) “The measurement of Scientific and Technological activities”, Oslo Manual, 93p.
[25] Strategic Development Council, “Roadmap 2030: The U.S. Concrete Industry Technology Roadmap”, 2002. http://www.eere.energy.gov/industry/imf/pdfs/concrete_rdmap.pdf
[26] Dixit, Avinash K. and Robert S. Pindyck (1994), Investment Under Uncertainty, (Princeton, NJ: Princeton University Press).
[27] Vinod K., Aditha N. S., Persaud, and T Jma Kumar, (1996) “To Terminate or Not an Ongoing R&D Project: A Managerial Dilemma”, IEEE TRANSACTIONS ON ENGINEERING MANAGEMENT, VOL. 43, NO. 3, August, pp. 273-284.
[28] Fojt M. (2003) “Innovations: Managing and measuring for R&D success: Could do R&D (much) better” in Strategic Direction, ISSN: 0258-0543, 2003 Volume: 19 Issue: 8 pp. 31 – 33.
[29] Lewis, T., Petrina, S., Hill, A. M., (1997) “Problem-posing—adding a creative increment to technological problem solving”, Journal of Industrial Education, 36(1), 5-35.
[30] Wertheimer, M. (1968). Productive thinking. Northampton, UK: Tavistock Publications.
[31] Mumford, M. D. Reiter-Palmon, R., & Redmond, M. R. (1994). Problem construction and cognition: Applying problem representations in ill-defined domains. In M.A. Runco (Ed), Problem finding, problem solving, and creativity, pp. 3-39, Norwood, NJ: Ablex.
[32] Miller W., Langdon M., (1999) “4th Generation R&D Managing Knowledge, Technology, and Innovation” John Wiley & Sons.

Denis Cavallucci
INSA Strasbourg – Graduate School of Science and Technology
LgéCo – Design Engineering Laboratory
24, Boulevard de la Victoire
67084, Strasbourg Cedex
FRANCE
33.3.88.14.47.55
33.3.88.14.47.99
denis.cavallucci@insa-strasbourg.fr
www.insa-strasbourg.fr