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Knowledge based approach for formulating TRIZ contradictions

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Abstract

The article presents how to innovate a product using information extraction from patents literature to identify and overcome TRIZ contradictions. Each initial inventive situation has to be formulated in terms of contradictions in order to use the most effective tool for problem solving provided by the TRIZ theory.

The authors propose, (1) an algorithm guiding the user to move from an indefinite problem situation to obtain a clearer problem formulation, following a process inspired to the ARIZ approach for fixing physical contradictions, and (2) some strategies and tools for selecting, acquiring and finally modeling the necessary information to improve the effectiveness in building the contradiction model.

All those strategies have been implemented in a knowledge management tool called KOM, working as an automatic patent searching engine based on a functional oriented search. An exemplary application is presented to explain how KOM is integrated in the problem definition process.

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Keywords: contradictions; TRIZ, KOM, FOS, patents;

1. Introduction

In the early phase of a design process, the problem space has to be narrowed down in order to transit from an initial situation to a goal state [1]. According to Newell and Simon's theory, this space should contain complete information about the initial state of the task (problem), information about the transformation function to move from the problem state to the solution, and information about the goal.

The most widespread classification divides problems into well-defined and ill-structured [2]. Well- defined problems have a definite solution process including a well-known initial state, a defined goal, and they require application of concepts, rules and principles from specific knowledge domains to reach a solution [2]. Unfortunately, in everyday life it is more frequent to encounter ill-structured problems, in which one or several aspects of the situation are not well specified, the goals are unclear, and there is insufficient information for the problem statement to solve them [3].

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Problems can also be classified according to similarities in the cognitive process that are required to develop skills for problem solving. In this direction we can cite the works of Getzels [4] and Jonassen's classification [5] that identified: puzzles, algorithm, story problems, decision making, troubleshooting, diagnosis-solution problems, rule-solving problems, strategic performance, systems analysis, design problems, and dilemma.

Also people from the TRIZ community like Ivanov and Barkan [6] have tried to classify problems in four typologies: manufacturing process problems, design problems, science and research problems, emergency problems.

To complete the overview on problem classification, it is useful to cite also the problem classification proposed by Altshuller [7]. Also this classification is based on the types of information required to solve it. According to him, problems can be classified in two categories, technical problems and inventive problems. We face technical problems when the designer knows where to find the information needed to solve them and how to use such information. Solving this kind of problems leads to a quantitative change of the technique. While, we face inventive problems every time the designer needs solving instruments not yet known in technical literature to achieve a qualitative change of technique.

The growth of interest in ill-defined problems, and consequently in design problem methodologies, has been radically changing the role of the designer, from a creative person highly skilled in the art, into an expert in design methods and knowledge management techniques. In this scenery, knowledge plays a pivot role in the problem solving activity and this is the reason why in TRIZ community many people have developed methods and tools to retrieve and organize information for contradictions formulation. A class of these methods is based on the cause-effect ontology, methods such as Root Conflict Analysis [8], and other systems dialogue based [9-11] guide the user towards a causal decomposition to identify the core of the problem, the contradiction. Other attempts have been done in using different methodologies such as the axiomatic design [12] or the theory of constraints [13] to better define a contradiction. Other approaches are based on text mining techniques to identify a network of contradictions from patents [14] or algorithms for searching similar systems by parameters extraction from text [15]. In addition, we have those approaches that aim to formulate contradictions according to the functional ontology, among these methods we mention FOS [16] that supports the identification of contradictions by means of a functional searching, tools to model problems by functional analysis [17], automatic systems for extracting functions contained inside patents [18], and knowledge bases in general [19].

The approach proposed in this article aims to formulate a problem in terms of contradiction as a conflict between two systems or two different configurations/working conditions of a same system. A computer aided tool, based on FBS ontology [20] is used to define this new problem formulation.

Section 2 collects definitions and examples dealing with TRIZ contradictions. In section 3 a four-step algorithm to formulate the problem according to TRIZ is proposed. Section 4 reports on KOM, a system for knowledge management to support the designer in the contradiction extraction. KOM generates different working directions from the inventive situation, followed by a systematic patent search to identify already known systems that can achieve such working directions. Section 5 presents an application of the knowledge management strategies proposed by KOM then, an evaluation of the performances of KOM patent search is reported in Section 6. Finally, last section concludes.

Nomenclature

B	Behaviour
CP	Control Parameter
EP	Evaluation Parameter
KOM	Knowledge Organizing Module
Ph	Physical Effect
S	Structure

2. An overview on TRIZ contradictions

An **inventive situation** is a typical case where the problem does not allow us to use known solving techniques to find a solution, while an invention is needed. Two main conditions define an inventive situation:

- Vagueness of the initial problem. The formulation is so vague that it contains many different problems.
- Contradiction. When we try to find a solution using the prior art, some conflict situations arise. These conflicts are called technical contradictions. In fact, technical systems are whole entities and, any attempt to improve a part (function, characteristic) of the system by known techniques leads to a not acceptable worsening of other parts (functions, characteristics) of the system.

A very representative problem to explain inventive problems is described by Altshuller himself.

Example: *For testing a new type of parachute, a small model of it is used for the simulation. The parachute model is placed in a transparent tube in which a stream of water flows. In this test it is essential to record the motion of vortices of water around all parts of the parachute (cell and suspension lines) by a camera. How to make the vortices visible? We tried to cover the parachute model with a soluble paint, but paint was faded faster and we had to stop testing very often. What to do?*

The formulation is so vague that it contains many different problems, i.e. changing the paint, the way to paint, the investigation system, etc.. The inventive situation consists of a description of the technical system highlighting the deficiencies: the absence of a certain characteristic or vice versa the presence of an undesired characteristic (harmful). Many difficulties that arise in solving inventive problems are influenced by attempts to resolve the initial situation without consciously moving from the "pile" of problems of the initial situation to a real problem.

According to TRIZ all systems develop themselves as the result of the accumulation of contradictions within the system. The amount of contradictions increases and their solution is possible through a breakthrough, i.e. an idea that comes up, a totally new conception. Consequently, finding solutions to inventive problems, or more in general improving technical systems, must include the identification and resolution of hidden contradictions within systems. The transition from the indefinite inventive situation to the problem and its model is described by Altshuller [7, 21-23] through three different types of contradictions.

Administrative contradiction. Something is required to make, to receive some result, to avoid the undesirable phenomenon, but it is not known how to achieve this result.

Let's take the example of parachute problem that is an administrative contradiction, in other terms it is not a problem but rather an inventive situation. Usually, an inventive situation is formulated like something is required to make (for achieving some result or avoiding the undesirable phenomenon), but it is not known how to do it. This type of contradiction does not contain any direction to address the answer.

Technical contradiction. An action is simultaneously useful and harmful or it causes Useful Function(s) and Harmful Function(s); the introduction (or amplification) of the useful action or the recession (or easing) of the harmful effect leads to the deterioration of some subsystems or the whole system, e.g., an inadmissible complexity of the system.

The administrative contradiction has to be turned in a technical contradiction, so transforming a given problematic situation into a technical problem. This helps to reduce the vagueness of the inventive situation.

In our parachute example, we can formulate the technical contradiction as in the following:

Example: To increase the time of video shooting is necessary to add significantly the quantity of paint placed on the parachute, but in this way we inevitably alter the measurement and the shape of the model.

Physical contradiction. A given subsystem (element) should have the property "P" to execute necessary function and the property "-P" to satisfy the conditions of a problem. Where "-P" could be defined both as the absence of P and the opposite of P.

The physical contradiction implies inconsistent requirements to a physical condition of the same element of a technical system. Each technical contradiction can be expressed in terms of a physical contradiction that represents the final reformulation of an inventive problem.

For the example of the parachute the physical contradiction is reported in the following.

Example: On the suspension lines there must be an infinite amount of paint (to increase the time of video shooting) and there should not be absolutely (not to alter the measurement).

3. From an inventive problem to its contradiction in four steps

As above mentioned, solving an inventive problem means to identify and eliminate the contradiction. Sometimes, the technical contradiction within a problem is clearly evident, other times it seems that a problem does not contain any technical contradiction because it is hidden within the problem conditions. In the following, we summarize in four steps the formulation process of the physical contradiction starting from an initial inventive situation. Where, the physical contradiction represents the most precise way to formulate an inventive problem, because it contains a precise specification of which direction should be taken and which parameters have to be used to model the solution. In particular, this four-step process is derived from OTSM-TRIZ [24] and it is based on the clear definition of the initial situation A, followed by the identification of an alternative situation B that can solve the situation A but introduces a new problem and so a contradiction. A schematic representation of the four steps is reported in Figure 1.

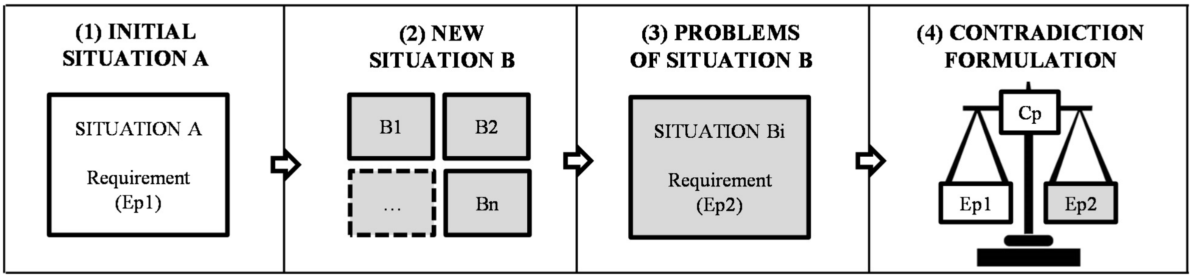

Figure 1. A schematic representation of the algorithm for problem reformulation.

(1)Initial situation A

The step 1 aims to clearly define which main requirement the solution must have to solve the initial situation A. This requirement has been called Evaluation Parameter (EP1) [24] and it represents the desired improvement (or creation) of a useful function or the decrease (or elimination) of a harmful function.

System A does not achieve a required function (EP1)

Example: *For the situation of the parachute, the EP1 can be defined as: the time of video shooting has to be long.*

(2)New situation B

The step 2 aims to identify a new situation B where EP1 is satisfied. New situation B could be defined by already known solutions/systems that can satisfy EP1 improving (or creating) a useful function or decreasing (or eliminating) a harmful function.

System A does not achieve a required function (EP1), so it has to evolve to a different system B to achieve the required function (EP1)

Example: *To increase the time of video shooting (EP1) many known solutions are possible:*

- *A new way to paint the model using the existing paint.*
- *A more effective paint to coat the model.*
- *Avoiding the use of paint and building a new device for shooting that can acquire the movement of transparent water.*

Choosing the first situation, where something has to be changed in the way the existing paint is used, the new situation B can be defined by an expert as: adding more paint on the parachute model.

(3)Problems deriving from situation B

The step 3 aims to find new problems (EP2) introduced by adopting the system B to satisfy EP1.

System B cannot achieve another requirement (Ep2),
that system A was able to satisfy.

Example: *If we add more paint to the parachute model (situation B) the measurement will be affected due to the alteration of the vortices (EP2) or the costs of test campaigns are higher (EP2) or etc.*

(4)Contradiction Formulation

In the last step, among all requirements/problems (EP2) extracted from situation B, we select only those which are in conflict with the requirement (EP1) of the situation A. Now the technical contradiction could be written in the following way:

System A does not achieve a required function (EP1); so
it has to evolve to a different system B to achieve the required function (EP1), BUT
System B cannot achieve another requirement (Ep2) that system A was able to satisfy.

Example: The technical contradiction is the following: initial system A does not realize a time of video shooting long enough; adding more paint (system B) we realize a longer time video BUT the measurement will be affected due to the alteration of the vortices.

Finally we have to transform this technical contradiction in a physical contradiction. According to the definition at Section 2, we have to find the property “P” to execute the necessary function and the property “-P” to satisfy the conditions of a problem. Such a property is called Control Parameter (CP) [24]. Here the final template for physical contradictions:

PhC#1: the CP has to be high to satisfy EP1, but doing that EP2 is not satisfied.
PhC#2: the CP has to be low to satisfy EP2, but doing that EP1 is not satisfied.

Example: The physical contradiction is the following:

- PhC#1 the quantity of paint has to be high for long time video shooting but doing that the vortexes alteration is high.
- PhC#1 the quantity of paint has to be low for a small vortexes alteration but doing that the time video shooting is short.

4. Using knowledge to support contradictions extraction and formulation

In this section we consider only the first two steps of the algorithm, (1) defining the initial situation A by the extraction of the requirement we want to satisfy (EP1) and (2) identifying a new situation B where system B satisfies EP1. In fact, there are often several ways for satisfying EP1, and for all these ways it is possible to find a new system B. This new system B satisfies EP1 but it introduces a new problem (EP2), in other terms it generates a contradiction.

For example, thinking about a nutcracker that breaks the shell but it also damages the kernel, system B can be found considering several solution ways as shown in Table 1. Each system B leads to a contradiction.

Table 1. System B generated as a modification of system A.

System B can be found as a modification of system A:	Solution ways
Change Working condition	Breaking nut in a very cold environment in order to weaken shells
Change system Configuration	Modifying the compression force according to the nut shape and dimension
Change Structure	Modifying the levers shape
Change Working principle	Using ultrasound breaking
Change Function	Opening nuts without cracking but by levering

TRIZ theory does not have specific tools for supporting the identification of the situation/system B, so the right identification of the contradiction is totally demanded to the user capabilities and knowledge. We have to use our background or creativity to imagine a system B. Several attempts were done by Altshuller before 1985 to assess a module for overcoming this problem, called ARIZ step 0, but it was abandoned in the last official version of ARIZ 85C. Litvin offered a partial answer to this problem by the Function Oriented Search-FOS [16]. Given an initial problem, FOS aims to find a new system that performs the same function. It is a method composed of eleven steps. Table 2 represents the first seven steps of FOS and their applications, in the last three columns we describe the limitations of that methodology. In particular, the third and fourth columns show which elements are missed by a traditional FOS. The next sections report on KOM, a system developed by the authors to support the steps 1, 4 and 5.

4.1. KOM a knowledge searching system to support contradiction formulation

The Knowledge Organizing Module (KOM) is a functional based search approach developed by the authors to extract knowledge from patent database [25, 26]. This computer aided system is a searching tool dedicated to who needs to formulate the contradiction finding an already known/patented system B. It is based on the FBS design ontology [20], that is introduced to decompose the functional concept in three levels [27]: function (F), behavior (B) and physical (or chemical) effect (Ph), e.g. *"crushing a nut"* can be decomposed in *"cracking the nut (B) by compression(Ph) for opening it (F)"*. This decomposition is suggested in order to create the targets for searching inside patent DB and ameliorate search results [28]. Both in KOM and in FOS, user has to define a function and an object representing the initial situation. The difference is the way KOM searches inside the patent database. KOM does not use directly the function and the object provided by users but it automatically processes these two elements by two actions: (1) a functional decomposition of the main function into behaviours and physical effect according to the FBS theory, (2) a semantic expansion of all words generated by the previous action.

In this way the initial user's query is so transformed in a set of queries, one for each physical effect contained in our physical effect library. Every query could produce a potential system B, differing from system A for its physical effect and suitable for completing our contradiction. At present this kind of semantic search is able to automatically associate the concept of *cracking nut* with other linguistic variations as *"opening or compressing a nut"*.

Like in FOS, KOM can search documents inside our field of interest (*e.g. cracking the nut*) or outside (*e.g. shellfishes cracking, eggs cracking, tablets cracking, etc*). Searching outside our field allows us to gain a more exhaustive view of the existing systems that can achieve the desired function (EP1). In fact, external fields can disclose new solutions based on the exploitation of new physical effects not yet developed in our field.

Table 2. The contact lenses sterilization problem by FOS approach. The last three columns describe limitations and suggestions.

FOS: steps 1-7	FOS: case study	FOS: shortcomings	Shortcoming examples	*Tools and References*
1. Identifying the key problem to be solved.	*1. Contact lenses must not be contaminated.*	1. Defining EP1 is not a simple task due to the complexity of the initial situation and its vagueness. Often, an initial situation contains more than 1 key problem, and these key problems can be translated in more functions.	*Potential alternative key problems:* • *Sterilizing lens preventing their corrosion.* • *Finding an alternative way to sterilize.* • *Avoiding infection of the eyes.* • *….*	*1. Functional decomposition according to the FBOS theory* • *D. Russo, et al. (2011), [29].* • *D. Russo and T. Montecchi (2011), [25, 26].*
2. Articulating the specific function to be performed.	*2. Sterilize contact lenses.*			
3. Formulating the required parameters and constraints.	*3. The effectiveness of the sterilization process is measured by SAL. For the medical field, $SAL<10^6$ (the microbial population has to be reduced from 1 million to 1 unit). In this process the lenses must not be damaged and/or changed their mechanical structure.*			
4. Generalizing the function.	*4. Remove bacteria from contact lens surface*	4. How to generalize the function?	*e.g. to disinfect, clean, remove, etc.*	4. Hypernymy relation: WordNet [30].
5. Identifying Leading Areas (industries or science branches).	*5. One leading area is the sterilization of medical devices, (surgical instruments). It has the same generalized function.*	5. People skilled in the art often identify existing systems using their background and experience, but personal knowledge is limited and the number of alternative solutions we can know is limited too, moreover we often search them in our field of expertise.	*e.g. existing solutions to sterilize hydrogen peroxide, peroxyacetic acid and all the other chemical solutions, vapor, aerosol spray, thermal treatment (overheating, boiling, freezing, etc.), high pressure, plasma, ultrasound, UV light, etc.* *How many others solutions do already exist to remove bacteria? Is the sterilization used in other fields? If yes, which?*	5. Methods and tools to identify already known solutions: • *Pointers to effects [21, 22].* • *Manually browsing prior arts.* • *Knowledge Organizing Module (KOM): a searching system able to automatically identify already known systems in patent literature [25, 26, 28].*
6. Identifying the best experts and/or institutions in the Leading Areas.	*6. Johnson & Johnson (New Brunswick, New Jersey)*			
7. Identifying the best existing technologies that perform a similar function in leading industries by using experts, industry registers and databases.	**7.** *Vapor sterilization has a very high effectiveness in removing bacteria without damaging polymeric surfaces.*			

5. KOM application

In this case study, the authors present an application of KOM for the steps (1) defining the initial situation A in terms of EP1 and (2) searching the system B that can satisfy EP1. The application takes into account the following inventive situation.

Problem: *We want to avoid eye infections that occur when dirty contact lenses are worn. To do that, we must sterilize their surfaces. How can we get sterile surfaces? We tried to sterilize using a chemical agent. The lenses are sterile, but their surface is damaged after few cycles of sterilization. What to do?*

(1)Initial situation A

In order to identify EP1 it is necessary to face the problem by generating many different perspectives of it. KOM manages traditional TRIZ tools as the laws of evolution [29], Inventive Standards and System Operator [25, 26] with creative methods such as linguistic triggers or Why-How method. All these different tools are suggested to obtain different points of view of the same problem, forcing the user to generate a wide range of alternative directions (described in functional terms). In Table 3 an example of how a problem changes if looked by different approaches.

Table 3. Different tools generate alternative perspectives for the lenses sterilization problem.

Tool	New problem perspective
Inventive Standards	*How to protect the surface from corrosion? (1.2.1)*
	How to modify the chemical agent to make it less corrosive? (1.2.2)
	How to modify the surface to resist to corrosion? (1.2.2)
Why-How	*How to use chemical agent?*
	How to sterilize lenses?
	How to remove bacteria?
	How to avoid eye's infection?
System operator	*How should surface of lenses be modified in advance in order to use chemical agent?*
	How can we sterilize surfaces even without using chemical agent?
	How should contact lenses be modified in advance in order to improve the sterilization?
	How can we remove bacteria even without sterilizing contact lenses?
Linguistic approach	*How can we remove bacteria even without sterilizing contact lenses?*

Sometimes the alternative problems generated by these approaches can be the same. All alternative problems for the lenses sterilization can be generated and collected by KOM as shown in Figure 2.

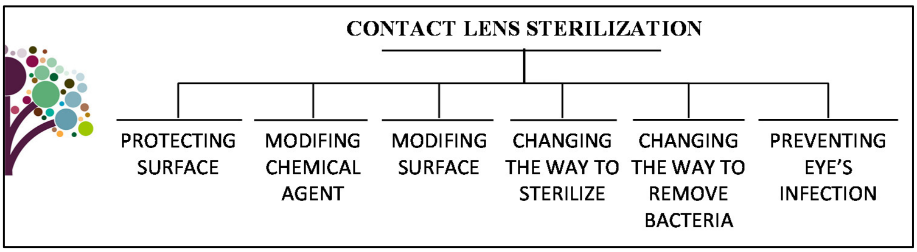

Figure 2. Alternative problems for the situation of contact lens sterilization. Output generated by KOM system.

Before moving to the next step, the user has to choose only one of these alternatives according to TRIZ evolution laws, and extract an EP1. Each alternative has its own EP1. Among these ways we choose "to change the way to sterilize".

(2)New situation B

This step aims to find, in patent DB, all alternative systems B "*to sterilize contact lenses*" in a different way from the initial one. In this case we are looking for systems differing by the physical effect (Ph) [28]. KOM works operating two actions:

1. Functional decomposition in Phs. It searches for alternative ways such as mechanical, thermal, acoustic, chemical, electric and magnetic sterilization.
2. Terms expansion: "sterilizing" is automatically associated to "disinfecting", "cleaning" and "removing". Furthermore a semantic expansion module searches all linguistic variations of any term composing the query (e.g. "to sterilize" is also searched as steriliz/sterilis-e, -es, -ed, -ing, -ation, -er, etc.)

The Figure 3 shows a map of the different ways for sterilizing contact lenses automatically found by KOM, in particular different ways are different physical effects. For every branch a list of patents is automatically provided. KOM identifies a pool of patents for every branch, but only 1 patent is then shown in the map. This allows to clearly visualize both which are the Phs already implemented at the state of art (if the patent search is limited to a specific area) and which Phs have been exploited in all the patent DB (for no limited searches). KOM offers several ways to manage such an extensive search [27].

In the lens sterilization case study, widening the search over the contact lens domain, it is possible to find other physical effects:

- JP2009058519: medical devices sterilization using x ray.
- RU2207323: water treatment using sterilization by x ray.
- WO2006083073: shoes sterilization using far-infrared.
- CN201709358: foods or foodstuffs sterilization using burning.
- KR20070088412: sterilization of dispensing beverages on draught using explosion
- CN201710543: treatment of the ear using sterilization by electro-static forces.

The map in Figure 3 shows a list of alternative systems B already known in the prior art. This map allows us to identify which systems are able to sterilize, keeping the lenses undamaged (EP1). At the same time, the exploitation of these new systems B will introduce one or more problems. Table 4 shows an explicative list of problems related to the systems for the sterilization by pressure and ultrasound. In particular, these problems are identified searching in patents resulting from KOM system.

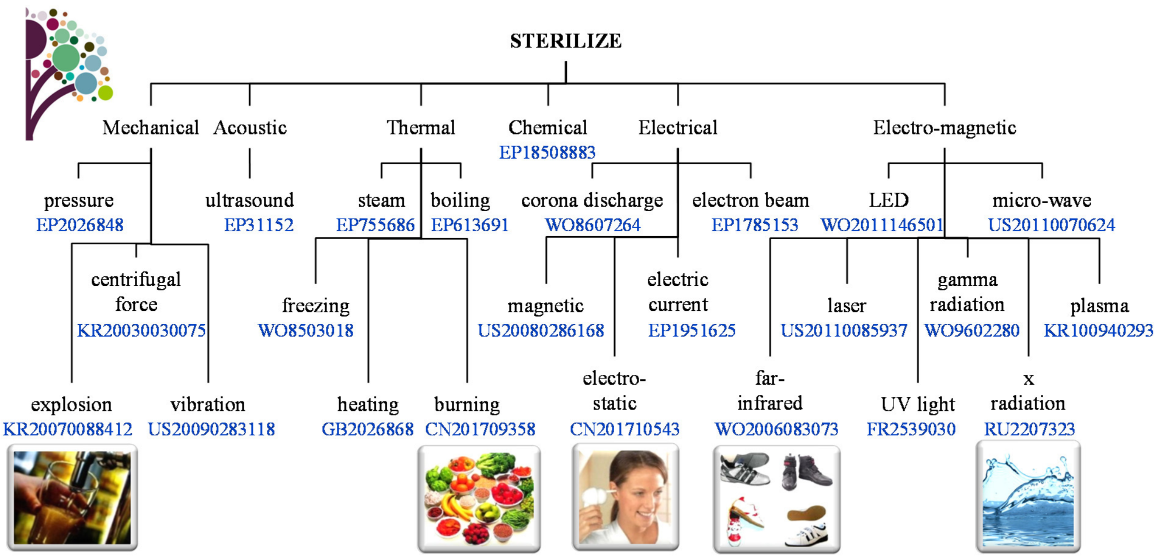

Figure 3. KOM output for the patent search of alternative systems B to sterilize contact lenses. Patent search performed across different fields.

Each row of the Table 4 contains a contradiction. For example:

The sterilization by ultrasound is able to keep lenses undamaged (EP1), but it spends long time for the sterilization (EP2). On the other side, the sterilization by chemical is a short time process (EP2), but it damages contact lenses.

The problems related to the system B are extracted from patent documents. In particular, EP2 can be identified by text mining techniques based on the recognition of predefined linguistic patterns that imply technical problems [18].

Table 4. List of contradictions formulated as a conflict between two alternative situations A and B. T

Contradiction				
Situation A		**Situation B**		
System A	Problem (EP1)	System B	Problem (EP2)	Patent document
Sterilization by chemical	*Damaged lenses* (undamaged lenses)	*Sterilization by pressure*	*Time consuming* (short time of the process)	US20110293471
Sterilization by chemical	*Damaged lenses* (undamaged lenses)	*Sterilization by pressure*	*Costly* (low cost of the process)	US20110293471
Sterilization by chemical	*Damaged lenses* (undamaged lenses)	*Sterilization by pressure*	…	…
Sterilization by chemical	*Damaged lenses* (undamaged lenses)	*Sterilization by ultrasound*	*Instability of vibrations* (vibrations stability)	US20050028848
Sterilization by chemical	*Damaged lenses* (undamaged lenses)	*Sterilization by ultrasound*	*Heavy* (low weight of the system)	US6183705
Sterilization by chemical	*Damaged lenses* (undamaged lenses)	…	…	…

6. KOM for searching existing technology: evaluation of performances

In this section, the authors present an evaluation of the effectiveness of KOM patent search according to recall and precision. In particular, this evaluation takes into account the search of the sterilization technologies patented in the field of contact lenses. The aim of this patent search was to identify the physical effects used to sterilize in the field of contact lenses by retrieving at least one patent for each Ph.

6.1. Evaluation

For the purpose of the evaluation we have manually built a pool of patents related to sterilization of contact lenses then. This pool has been created considering the IPC patent class (A61L12) related to patents for contact lenses sterilization (around 1330 patent families[a]). This collection of patents was manually cleaned up and the final pool has contained 1205 patent families related to the sterilization of contact lenses with English text (also abstracts with automatic translations were included). Then each of the 1205 families has been manually classified according to the physical effects (Ph) used. According to such a classification, physical effects (Ph) used to "remove bacteria" (F) are 19, as shown in Table 5. The sum of families of all physical effects (Ph) is higher than 1205, because some families claimed more than one physical effect or they use them together synergistically (either simultaneously or consecutively).

On the other side, the automatic classification has been obtained, running KOM inside the patent class A61L12 and not inside the manually refined pool. The results obtained are shown in Table 5.

Table 5. Recall and precision for each Ph contained inside the pool of contact lenses sterilization.

PHYSICAL EFFECTS	MANUAL	KOM	
	N° patent family	Rec.	Prec.
Centrifugal force	2	0,50	1
Pressure	31	0,23	0,29
Vibration	28	0,32	0,82
Boiling	9	0,44	0,67
Freezing	1	1	0,50
Gas/steam	36	0,44	0,36
Heating	125	0,66	0,88
Ultrasound	43	0,36	1
Chemical	1009	0,04	0,77
Corona discharge	3	0,67	1

PHYSICAL EFFECTS	MANUAL	KOM	
	N° patent family	Rec.	Prec.
Electric current	35	0,14	0,71
Electron beam	1	1	1
Magnetic	4	0,40	0,67
Gamma radiation	5	0,40	1
Laser	7	0,43	1
LED	15	0,27	1
Microwave	16	0,31	1
Plasma	14	0,21	1
UV light	50	0,40	0,95

6.2. Results discussion

The discussion takes into account the comparison between the automatic classification of patents related to the contact lens sterilization and the automatic patent search conducted by KOM. As the Table 4 shows, KOM has found 22 physical effects (Ph) for sterilizing contact lenses, identifying all the 19 (Ph)s resulting from manual classification. It has identified also 3 more physical effects (sterilization by burning, infra-red and explosion), but these are false positive results. These results have been obtained because patent texts really mentioned those effects but not to sterilize. In those cases, Natural Language Processing (NLP) tools could be very useful to eliminate irrelevant results.

The precision we obtained for each effect is very high, in particular if we consider all the retrieved (Ph)s the average rate of precision is 0,77. This means that, with high probability, patents retrieved for each (Ph) effectively claimed such a (Ph) to sterilize contact lenses. This is achieved by an algorithm that greatly favors precision by reducing recall. Thus, regardless concept expansion on multiple levels (F) and (B) and linguistic expansion, recall remains low because of the way high precision is obtained.

Finally, KOM found some examples of patents classified in more than one (Ph) because they claim different physical effects (Ph):

- ***WO9315772:*** *"A process … wherein said vessel comprises a collapsible pouch, and wherein said collapsible pouch expands to a visibly apparent distended condition during said irradiating step under the pressure of vapor produced by heating the disinfecting solution to its boiling point".*

7. Conclusion

This article presents how KOM, a knowledge management system developed by the authors, can support the designer in formulating a problem in terms of contradiction as a conflict between two situations: (A) the initial problem situation and (B) a new situation created in the attempt to solve the initial problem situation using an existing system.

Starting from an undefined problem situation, KOM guides the designer to generate different alternative problems. Once an alternative is selected and described as a desired requirement to achieve (EP1), the automatic patent searching tool (integrated inside in KOM) looks for already known systems that can satisfy that requirement (EP1) using different physical effects. As shown in the results of KOM application, in the contact lenses sterilization field, the automatic patent searching tool has been able to find all the 19 physical effects to sterilize contact lenses that are patented in this field.

Moreover, has been demonstrated that KOM is able to find alternative systems (differing in Ph) also belonging to other technological areas (sterilization of medical instruments, shoes, foodstuffs, beverages dispensers, waters and body treatments). Like in FOS, new technologies, not yet used in the contact lenses field, have been identified to reach the same goal (x-ray, fra-infrared, burning, explosion, electro- static). At the difference of FOS, some steps of the algorithm have been automatized and improved, integrating with known TRIZ tools.

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