Linking Contradictions and Laws of Engineering System Evolution within the TRIZ Framework

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Tools and methods developed during the era of quality and optimization have shown their limitations and become inappropriate in the context of the requirements of innovation. Nowadays the need to rebuild design practices in enterprises is strongly felt both in terms of human skills and methodological expertise. In part, a way to face the innovation era's difficulties has been provided through the theory of inventive problem solving. This theory represents a significant breakthrough in driving problem statement and solving in a direction that is expressed through the idea that technical systems are driven by objective laws. A second postulate concerns the notion of contradiction, but so far only few contributions have addressed the relations between laws and contradictions. This paper, through a qualitative approach, presents a solution to this limitation and proposes a possible use of laws within the choice of the appropriate conflicting pair, prior to the use of any TRIZ solving techniques. Tests to observe the impact of the proposed approach were conducted in a French engineering 'grande école' during three semesters with 180 engineers. The contribution of this paper is twofold. On the one hand, there is a theoretical contribution to the theory of inventive problem solving. In addition, the proposed method offers especially TRIZ practitioners new ways for problem understanding and problem formulation.

Introduction

Since the socio-economic paradigm of the past seven decades has turned towards enhancing value through statistically balancing procedures, elaborated engineering design theories have been (and still are) mainly 'optimization-driven'. When observing actual approaches empowered by industries, six-sigma-like methodologies are still employed and have proven their financial usefulness in most cases (Thirunavukkarasu et al., 2008). Nevertheless, an increasing number of researchers are now addressing the innovation paradigm and are actively trying to contribute to the elaboration of a new know-how which differs from established optimization theories (Moehrle, 2005). Some research is conducted within the context of the Theory of Inventive Problem Solving (TRIZ). This theory proposes a framework which is based on three major axioms (Cavallucci & Khomenko, 2007):

- First axiom: Technological systems do not evolve at random but according to objective laws of evolution. These laws do not depend on humans. They should be observed, formulated and used in order to develop efficient methods of problem solving.
- Second axiom: Technological systems do not evolve at random but in the course of overcoming contradictions. In order to come up with a breakthrough idea we should find a way to overcome contradictions.
- Third axiom: A specific problem must be solved in accordance with restrictions concerning the specific problem situation and a view to the peculiarities of every specific case, and can thus not be solved generally. A robust solution is a solution that involves as small a number of new resources as possible.

The Laws of Engineering Systems Evolution (LESE) constitute the first of TRIZ's main axioms. By means of observing expert applications of TRIZ, teachers/professionals provide

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their students/clients with some theoretical elements related to LESE as well as vivid illustrations concerning their relevance in various cases alongside anecdotes of actual situations in which they were helpful in unlocking/orienting a study in the appropriate direction.

If we look carefully at what has been proposed and published on the subject of LESE, it might even be understood that Altshuller's intention was not to build upon the theoretical description of these laws a useful operational way to benefit from them. But although there are some interesting theoretical explanations associated with practical attempts (Salamatov, 1991), most newcomers to TRIZ realize, once they have dedicated some time to analysing the TRIZ literature and other related material, that none of the available tools or techniques propose a practical utilization of LESE.

In this paper we propose a bridge between LESE and contradiction thinking, and link this bridge to the design situation (represented by positions on S-curves). As a result we will answer the question how to order contradictions as starting points for further instruments. Therefore, first we introduce nine LESE, grouping them in a static, dynamic and kinematic set. Second, we discuss thinking in contradictions as a major element of TRIZ. Third, we introduce evolution hypothesis to connect LESE with contradiction elements and parameters. Fourth, we show how this connection may be used to prioritize contradictions in a design situation. Fifth, we present results from a test of the suggested process. Finally, we conclude with some remarks.

The Notion of Law from a TRIZ Point of View

Laws Seen from Altshuller's Viewpoint

The first occurrence of the term 'law' expressed from Altshuller's viewpoint (as it is publicly known) can be found in his article 'An essay on the psychology of inventiveness' from 1956 (Altshuller & Shapiro, 1956). In this text, references were made among others to Marx and Rubinstein; furthermore, the limitations of current visions such as enlightenment and trial-and-error procedures were stated. The conclusions clearly expressed the vision that technical systems were evolving according to laws and that these laws should be utilized in designing methods related to inventiveness. Here, 'usability' was put forward in the final sentence which contains the following perspective 'the objective of the psychology of inventiveness is to be translated into practice: its inherent laws must be used during the development of scientific methodology to work on inventions'.

There are nine laws which characterize the evolution of technical systems. Each of these laws plays a particularly significant role at a given stage of its lifetime. A detailed description of the nine laws can be found in Salamatov (1991). In our paper we will use the structure presented in Figure 1 to introduce them, as well as the following definitions:

Law 1: Completeness: Any technical system results from a synthesis of several parts into a single whole. In order to be viable, the main components of this technical system have to be present and perform within a minimal working efficiency.
Law 2: Efficiency: In order to make a system viable, the energy flow that drives it must pass through all of its main components.
Law 3: Harmonization: In order to maximize a system's performance, all of its main components must be either coordinated or un-coordinated.
Law 4: Ideality: During its evolution the technical system tends to improve the ratio between its performance and the expenses required to attain this performance.

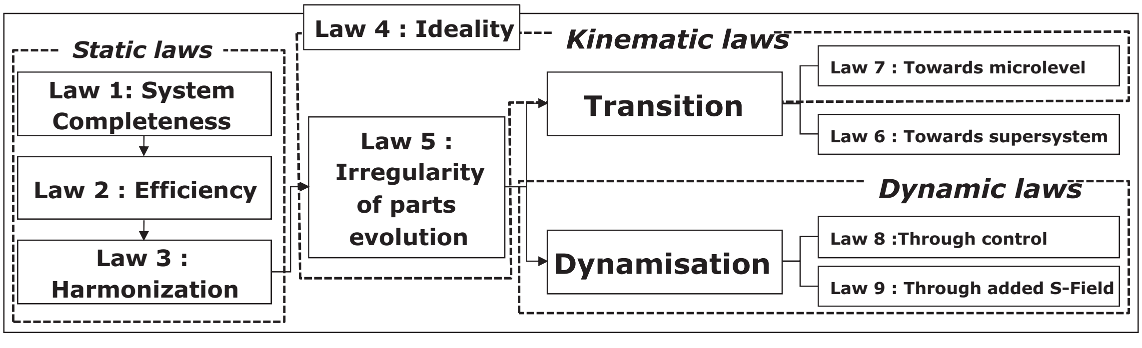

Figure 1. Structure of the Nine LESE

Law 5: Uneven development: Components of technical systems evolve irregularly. The more complex the system, the more irregularities one gets. These irregularities lead to the birth of new contradictions preventing its evolution.
Law 6: Transition to the super-system: In the course of their evolution, technical systems merge to constitute bi- and poly-systems. In the future, the system pursues its evolution as a part of the super-system.
Law 7: Transition to the micro-level: The evolution of the 'tool' element within a given system begins on the macro-level and inclines toward the micro-level. This evolution is brought about by the advantages of using properties of dispersed materials and particles of physical fields.
Law 8: Control through dynamization: In order to improve their performance, rigid systems should become more dynamic. By means of dynamicity we intend: evolution towards more flexible and rapidly changing structures, adaptability to changes of working conditions and requirements of the environment.
Law 9: Control through added substance-field systems: In order to improve their performance, systems should become more controllable. By means of controllability we intend to follow elementary rules expressed in the inventive standards.

Recently, Vladimir Petrovich has published several interesting articles in this respect (Petrovitch, 2005, 2006). He features a more structured way of presenting the laws compared with Altshuller's traditional division into 'static', 'kinematic' and 'dynamic'.

Attempts at Understanding

Ever since the TRIZ Body of Knowledge first appeared in the western world (in the early 1990s), LESE have attracted the attention of many industrialists, researchers and consultants. After the reception of whatever was publicly accessible, quite a few interpretations were expressed in which various terms qualifying the laws can be found, such as 'trends', 'logics', 'tendencies', 'patterns'. What is mainly argued by several authors, either in their articles, in their public presentations or in various web forum discussions, is that the term 'law' should be carefully employed; moreover, the use of LESE from description to prescription should not lead to a 'naive' form of forecasting (Gavin & Mandal, 2003).

In 1999, one of the authors undertook an attempt to share Altshuller's findings with scientific communities regarding the laws (Cavallucci & Weil, 2001) through the postulate that they could play a role in orienting designers in projects with inventive aims. After this publication, some attempts at utilization by means of software tools arose (Mann, 2003) and met with positive feedback in education, modest success in industry and rejection in scientific communities. Consequently, one cannot help wondering, whether Altshuller's laws may not still be underused at the present time.

TRIZ's Contradiction Model

After having introduced the LESE, which represent evolution paths of technical systems, we will now discuss TRIZ's contradiction model, which represents the core of the problem situation. The formulation of a contradiction comprises three types of components: elements, parameters, values (partially interpreted from Khomenko & Ashtiani, 2007).

Elements (E) are components of a system. From a syntactical point of view, they can either be subjects, names, nominal groups or complements to an object. (Example: the hammer drives in the nail; E = hammer). The character of an element can (within the meaning of TRIZ) constantly change its systemic level according to the description which is given by it. Thus 'the hammer inserts the nail' can become 'the anvil inserts the nail' from the point of view of another expert. In the second case, E = anvil. For a third 'the man inserts the nail', etc.

Parameters qualify elements in giving them a specificity which is the translation of explicit knowledge from the observed field. Thus, parameters are mainly names, complements to objects or adverbs, the form of their expression is multiple, sometimes contradictory when expressed by different experts. They are divided into two categories:

– Action Parameters (AP): here the designer has the capacity to modify them (the designer can decide to design an anvil of large volume or small volume, in this case volume = AP).
– Evaluating Parameters (EP): having the capacity to evaluate positive and negative aspects resulting from the designer's choice. The consequence of designing an anvil with a large volume is an increased facility of inserting the nail; in this case facility of insertion = EP).

An interesting aspect we observed when trying to identify whether a parameter was 'active' or 'evaluating' is that an AP has two logical directions pointing to interesting outcomes, while EP possesses a single logical direction (the other seems absurd). As in our example, we can easily imagine that the 'volume of the anvil' is of interest in both cases, whether it is 'smaller' or 'larger', therefore it represents an AP. In contrast, the 'facility of insertion' seems interesting only if 'improved', as it would be nonsensical to wish for a decrease in the 'facility of insertion', this represents an EP.

The values are mainly adjectives employed to qualify a parameter (the volume of the anvil must be important; in this case important = Va). Let us note that the fundamental aspect of the concept of contradiction (when elucidated at the physical level) lies in the qualitative opposition of the values and the fact that if V is in a state that involves positive aspects, then it is essential to investigate the opposite of V (Vā) (its antonym in terms of linguistics) to highlight and to prove the contradictory aspects of the analysis. Thus, an anvil of a large volume involves a facility of driving and an anvil of a small volume involves a facility of handling (in this case large = Va and small = Vā).

Finally, a last step to highlight the concept of contradiction is to make certain that the opposite assertions are also true.

- Will a large mass of anvil invariably involve a minor facility of handling?
- Will a low mass of anvil invariably involve a minor facility of driving?

If the answer is yes in both cases, we can consider the contradiction valid (TCx). TCs represent a partial modelling of knowledge associated with the description of the problems involved in the evolution of the hammer.

Subsequently, the scheme shown in Figure 2 is used for a graphical representation of contradictions.

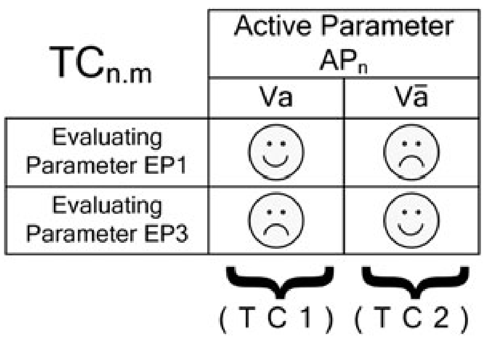

Figure 2. Generic Contradiction Table

Evolution Hypotheses as a Bridge between LESE and Contradictions

In the course of our analysis of the TRIZ Body of Knowledge, we formulated a statement on where, among all other tools, techniques and knowledge bases, LESE are tacitly or explicitly present (see Table 1). It is clear that, until now, there has been a missing link between LESE and contradictions.

A first objective of this study is to consider that once a group of contradictions has been revealed, our initial question may be the following: 'How can contradictions be ordered in

Table 1. Tacit or Explicit Presence of LESE within the TRIZ Body of Knowledge (see also Altshuller, 1984, 1991, 1999; Pinyayev, 1990)

	Element from the TRIZ Body of Knowledge	Type of Laws Present	Where
Tools	Multi-screen analysis	Tacit	From past to present and from present to future
	Matrix	None	
Methods	Substances-field modelling	Tacit	Within the transformation logic from initial situation to solution model
	ARIZ-85C	Tacit	Through Inventive Standards use, and IFRs formulation
Knowledge bases	System of inventive standards	Explicit	Through the structure of classes and sub-classes
	Inventive principles	None	
	Separation principles	None	

accordance with the fact that *they represent an opposition to a specific law?'* The expected result is the ability to ensure that the treated contradiction (consequently being solved using TRIZ tools) is standing in the way of a specific law.

According to our observations, parameters (the components of contradictions) can emerge based upon five distinct situations:

- when expressed by experts to describe a problematic situation;
- when extracted from a text in which the problematic situation is described;
- when disclosing the parametric character of a system evolution (in multi-screen scheme description);
- when discussing the maturity of the studied system with regard to LESE;
- when populating incomplete contradictions.

Each of these five phases of problem analysis situations presents an opportunity for disclosing parameters and compiling them in a list that can be used to populate contradictions. A first comment is that the fourth item on the list appears to be interesting as regards our problem, since in the course of the LESE observation stage, parameters can emerge, and tacitly imply a link with the law from which they emerge. But these situations are not systematic and the four other points are still not clearly showing the link.

There is need for an intermediary component during problem expression, whose role is to have, in its cognitive resonance, the capacity to be extracted from laws and within its structure, when pronounced, to provoke the emergence of a parameter in the expert's mind. Based on this statement we draw the hypothesis that a simple sentence, namely an 'evolution hypothesis' (EH), takes the following form:

> If [technical system] is evolving in [law direction] then we can draw a coherent picture of its probable future saying that: a [technical system] [describe its probable future state if one of its characteristic is logically improved].

For example, the observation of Law 2 (energy conductivity) for a screwdriver will consist in discussing how the energy flow within the system's components may not be lost in order to attain its main function of use. If one supposes that there is an ideal unscrewing position and that, whenever the user deviates from this ideal position, the screwdriver slips, wasting energy, we can derive the following evolution hypothesis:

> EH: A [screwdriver] that [never slips from its ideal axial position when unscrewing].

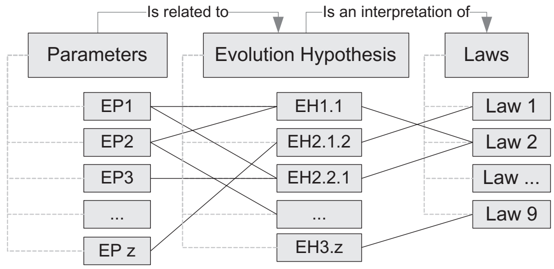

Figure 3. Contradictions and Laws Linked through Evolution Hypothesises

As a result of this EH, a link or the emergence of a new evaluating parameter (EPn) 'Capacity to remain coaxial with screw axis' can be formulated and listed as a parameter linked to law 2. The consequence will be that each TC possessing this parameter (among its two EPs) will be correlated to law 2.

To summarize, an evolution hypothesis (EH) can be seen as a thinking component to facilitate links between contradictions and laws. EHs are literal interpretations of given laws, expressed in the form of a sentence. This sentence is the result of a possible direction the technical system may take in his evolution. The semantic interpretation of a law will obviously bring out more detailed and specified elements (parameters, values, new elements) than the generic expression of a law (its postulate). By observing and analysing how these elements may refer to a list of parameters aiming at evolving in an appropriate direction, it is possible to establish a semantic proximity unifying a parameter to a specific EHx (Figure 3).

Linking Laws to the Design Situation

Assuming that a list of contradictions has been built according to the frame TCn [APx; EPn; EPm], for ranking contradictions according to laws, we need to organize the arrangement of laws with regard to the design situation. We now encounter a problem that was already disclosed by Altshuller (1984) where he underlines the importance of identifying the maturity position along the 'S' curve. This kind of positioning is one of the most challenging subjects of research in industry today. The findings of this research is aimed at reliably indicating the maturity of a technology and forecast in a narrowest spectrum of variants where the studied technology is moving towards (Kucharavy & De Guio, 2005).

This is not included in the scope of our current research, but the necessity to move

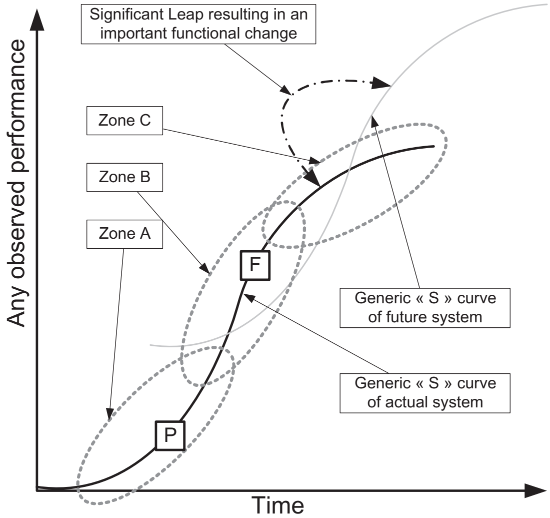

Figure 4. Two Cursors along Two Generic 'S' Curves

forward induces us to simplify the approach (even if we assume introducing a significant dose of imprecision) by inviting decision makers, along with the whole study team, to locate both present and future situations intuitively on two 'S' curves (based on their expertise regarding the treated subject).

In Figure 4, the present cursor (P) represents the current situation. Prior to this, an approximation using the approach developed in Altshuller (1984) can be used to lead management, marketing and R&D representatives to an agreement on the current situation.

The future cursor (F) represents the aim of the study. It clearly indicates whether the company aims at developing a totally new concept or at effecting a slight improvement. Usually, the 'S' curve positioning is supposed to assist in such decisions, but in our case, again, the strategy of the company should provide R&D with a clear notion of 'how important' it is to accept the leap, even though big companies often launch several alternatives (from slight improvements to pure research) anyhow, in order to move on carefully while protecting possible inventive solutions, representative of a significant technical leap in their technical system's evolution.

In order to attribute a specific importance to certain laws when a specific configuration of cursors P and F is given, we have tried to interpret Altshuller's texts as well as chapter 5 of Salamatov's book (Salamatov, 1991). According to our understanding of this literature, the following coefficient pre-set settings were drawn up:

- Case 1: $\because$ P $\in$ ZA $\wedge$ F $\in$ ZA $\therefore$ L1 = 4; L2 = 3; L3 = 2; L4 = 2; L5 = 1
- Case 2: $\because$ P $\in$ ZA $\wedge$ F $\in$ ZB $\therefore$ L2 = 4; L3 = 3; L4 = 2; L5 = 1
- Case 3: $\because$ P $\in$ ZA $\wedge$ F $\in$ ZC $\therefore$ L2 = 4; L3 = 4; L4 = 2; L5 = 1
- Case 4: $\because$ P $\in$ ZB $\wedge$ F $\in$ ZB $\therefore$ L3 = 4; L2 = 4; L4 = 2; L5 = 1
- Case 5: $\because$ P $\in$ ZB $\wedge$ F $\in$ ZC $\therefore$ L3 = 4; L2 = 3; L4 = 2; L5 = 1
- Case 6: $\because$ P $\in$ ZC $\wedge$ F $\in$ ZC $\therefore$ L3 = 4; L4 = 2; L5 = 2
- Case 7: $\because$ P $\in$ ZA $\vee$ ZB $\vee$ ZC $\wedge$ F $\in$ ZA^{+1} $\vee$ ZB^{+1} $\vee$ ZC^{+1} $\therefore$ L6 $\wedge$ L7 $\wedge$ L8 $\wedge$ L9 = 2

The aim of each of these statements is not to indicate an accurate assumption, but to focus attention on one specific law (or set of laws) rather than another, as suggested in Cavallucci and Weil (2001). The arrangement of laws according to importance will also have an impact on each parameter they are associated with.

In order to be able to modify these presettings, the coefficient associated with each law (a value from 0 to 5) has to remain variable. From the position of each coefficient, we have deduced a multiplying factor dedicated to raising the importance of certain parameters.

This multiplication has the objective of influencing the weight of a contradiction including these parameters. The contradiction's weight is therefore as follows:

$$\text{Value of TCn} = \text{Coef. APx} \; (\text{Weight EPn} \times \text{Max. coef laws} + \text{Weight EPm} \times \text{Max. coef laws})$$

where,

Max. coef laws: correspond to the maximum value (from 0 to 5) of the coefficient attributed to laws in relation with a given parameter,
Coef. APx: correspond to the influence an active parameter switched from Va to $\not\equiv$Va has on its associated EPs to provoke their evolution towards a desired state.
Weight EPn,m: the associated value attributed to a given EP corresponding to a company's priority. Here, the notion of ranking EP can be used in order to classify all EPs from the list.

Each EP from the list of EPs, that has been extracted from the contradiction formulation and MSA and linked to LESE through EHs, will then respectively be impacted by the existence of a link and its importance. This importance is directly associated with what has strategically been established in the 'S' curve observation and the predominant law within the specified context.

The formula which attributes a value to a TC remains a qualitative approximation, but allows us to postulate that LESE (from the first axiom) influence the ranking of contradictions (from the second axiom).

Towards a Procedure for Operating Simple Problem Convergence to Solution Concepts

In this section we would like to summarize our proposed framework by means of an algorithmic representation (Figure 5). This representation also includes other basic TRIZ elements that are not described in this article but on which further information can be found in Altshuller et al. (1989).

Steps 1 and 2 are supposed to reduce the observed system to its essentials. Usually reduced down to a single but vital one, a main useful function can only be described by the set of elements forming an undividable group for delivering this function.

Step 3.1 is dedicated to a multi-screen scheme analysis, through the description of evolving parameters (from past to present in all three lines of the systemic representation), a first list can be established as well as a first set of EHs.

Step 3.2 can be either conducted in parallel with or following step 3.1. This stage consists in observing your potential system evolution regarding each law (from 1 to 9). According to these observations, a second set of EHs can be formulated and the first list of parameters enhanced by a second set of new ones (redundancies should be avoided).

Step 4 consists in merging EH1 and EH2, mostly because in our entire protocol of testing, we have observed redundancies in EH formulation. As a result of this stage, a single list of EHs should be kept for the rest of the study while monitoring the relations between parameters and EH2 from step 3.2.

Step 5 consists in linking the two resulting lists (of parameters and EHs). Some links to previous steps are to be conserved. New ones, linking all insulated parameters with one or several EHs, are to be created.

Step 6 is dedicated to contradiction synthesis. Taking into consideration the typology of a contradiction, contradiction templates are to be filled with all available parameters from the list. We have observed that many spaces in contradiction templates are vacant at first. It is necessary then to disclose the 'missing' elements (either parameters or values) in order to validate all contradictions completely.

Step 7 proposes weighting each contradiction according to the formula expressed above and choosing those to be involved in a solving process.

Steps 8–11 are devoted to the use of TRIZ methods and tools. Depending upon individual skills developed in TRIZ learning and practice, a proposed path regarding the use of principles, standards or ARIZ is described in Altshuller et al. (1989).

Test of Procedure

In order to evaluate the relevance of our approach, represented in the form of a teachable and usable procedure (Figure 5), we tested it over three semesters with 180 engineering students in their fifth year (one semester before graduation) from seven different engineering departments (Civil Engineering, Topography, Mechanical Engineering, Plastics Engineering, Mechatronics, Electrical Engineering, Building Services and Energy Conservation Engineering).

The syllabus of the course was divided into two sections:

- A series of seven theoretical 2-hour lessons (14 hours of lecture per student).
- A series of seven directed work sessions of two hours' length, in which a simple object from everyday life was chosen and studied (14 hours of directed work).

The evaluation of the directed work consisted in a vindication of choices made and results derived in a hearing presided over by a jury. Additionally, a written report giving feedback on this work had to be handed in to the jury. Apart from a classical evaluation, this test intended to focus on the relevance of the utilization of laws. With a view to the appropriate interpretation of laws regarding their study as well as choosing (according to the approach developed by us) a relevant set of contradictions to be solved using TRIZ techniques.

During the first semester, fundamentals of TRIZ basic theory were taught (all topics related to TRIZ and requisite for conducting the directed work). An evaluation of the study results was undertaken and emphasized several limitations:

- Out of 45 students and 17 project teams, only three teams addressed relevant contradictions properly (coherent with laws analysis). The remaining teams either completely skipped the utilization of laws or totally separated the interpretation of laws from their solving part. As a result, the theoretical period only had a weak influence on the overall study.
- During the second semester, the same model of course and directed work was

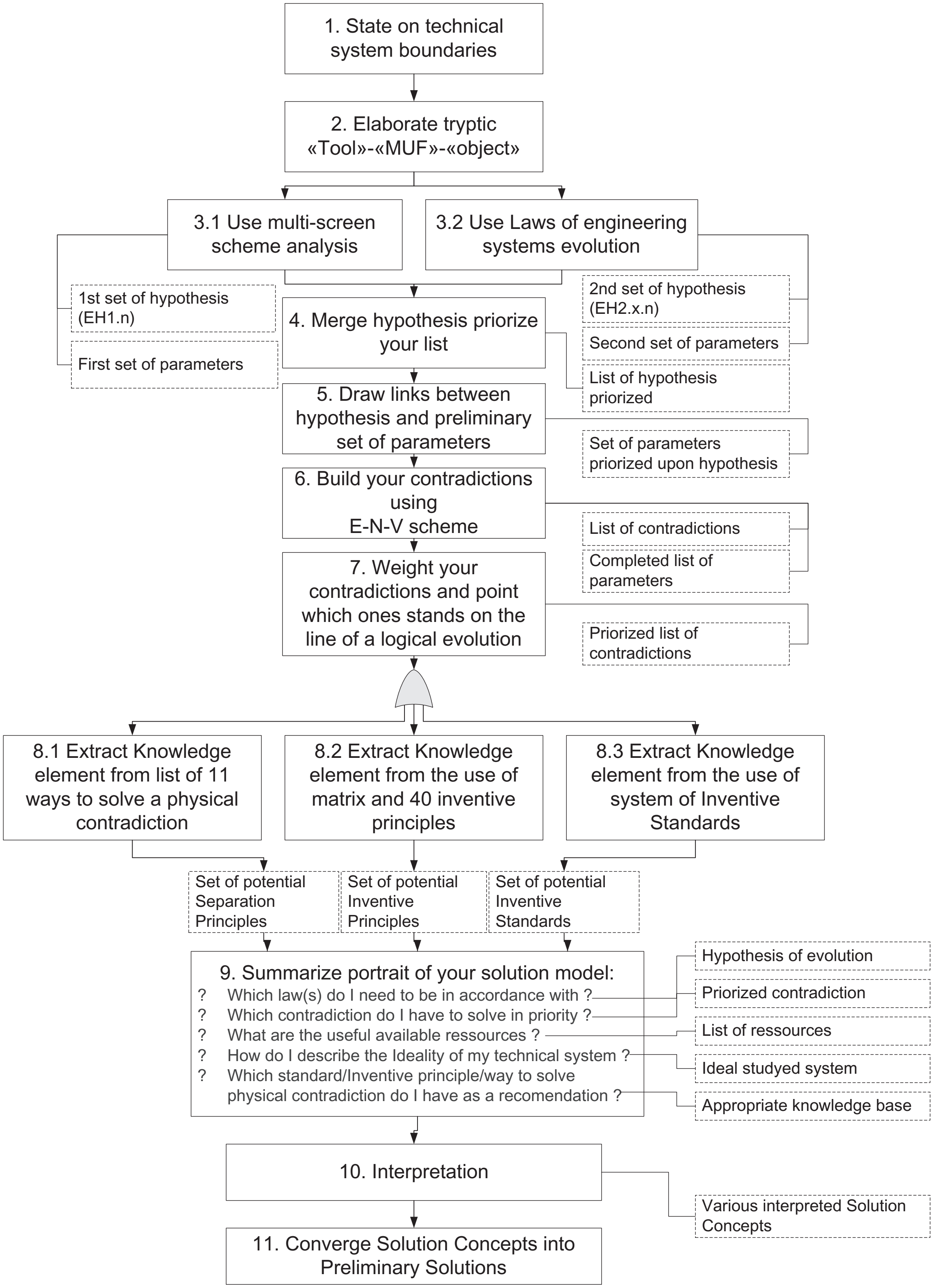

Figure 5. Flowchart of the Proposed Framework
MUF = main useful function, E-N-V-scheme = 'element-name of the feature-value-scheme'.

offered to 70 students forming 33 project teams. In addition to this, the theoretical content was restructured to introduce the idea of evolution hypothesis and its connection with other classical basic TRIZ elements.

- After this, the evaluation showed that 12 teams (out of 33) had obtained positive results in choosing a reduced set of appropriate contradictions, based on laws interpretation. The others had not fully respected the proper procedure and consequently, laws – although interpreted – were used for a post-evaluation of solution concepts rather than for addressing a relevant contradiction prior to the solution process.
- During the final semester, 65 students and 28 projects were involved in the test. This time we modified the process by introducing an online java software application, TRIZAcquisition, for the conduct of directed work sessions. This application was created as a result of a formalized ontology of TRIZ basic concepts using protégé V2.0.
- Following this, 25 project groups proposed a relevant contradiction choice, using laws interpretation appropriately. The remaining teams skipped this step mostly due to time resource limitations.

Discussion

Through the subject treated in this article we wanted to emphasize that LESE, as they were elaborated and presented by Altshuller several decades ago, were aimed at being fully integrated into the scope of TRIZ's theory usage. Up to now (as far as available written and published material goes), we have only found contributions which either aim at clarifying existing laws (descriptive contributions), re-interpreting these laws or trigger designers' imagination by means of utilizing these laws (using them along with pointed illustrations) to forecast a 'brainstorm-oriented' portrayal of what the system is going to look like in the future.

This paper was aimed at proposing a possible use of LESE within the context of contradiction choice (ranking). The tests undertaken for the evaluation of the benefits attached to our approach through three semesters and with 180 engineering students assigned to 78 project teams have shown that the proposed formalism, when understood and put into practice within a study, not only meets the initial target (a relevant use of LESE) but also accelerates the mastering of TRIZ basics, which it usually takes much longer to acquire. It is commonly acknowledged that extensive periods of learning, combined with a considerable amount of practice, are required to be able to observe the result of a relevant use of laws within a study. According to the accumulated data, we evolved from 15%, via 45% to an eventual 75% in relevant use; this encourages us to improve our approach and observe its possible perspectives even further.

A first obvious limitation is that it is difficult to generalize the developed method, since many elements have been qualitatively evaluated by users, and thus there is a direct dependence upon the accuracy of their perceptions. But what we are targeting is at a crossroads of human and engineering disciplines. If the second is easy to manage in terms of accurate formalism, the first is often qualified as 'science of the imprecise' (Moles & Rohmer, 1990). Further development will nevertheless be aimed at reducing the zones of imprecision within our approach.

A second point we have not yet clarified is the fact that our tests were set within an educational context. Although we were in the very last period of the engineering curriculum, and the students involved already possessed some industrial experience (through various internships), we did not expose our postulates to a relevant number of industrial situations. Nevertheless, the three cases in which this was done so far turned out promising perspectives. The very next step in the process of improving our approach will therefore consist in the enhancement of its robustness. Among others, one of our initial working hypotheses was that if industry has resisted the introduction of TRIZ, this was often due to the lack of a robust formalism that could easily be taught to engineers and practised within evaluated procedures. We believe that our partially achieved results can contribute to a more formal and relevant TRIZ practice.

Conclusion

In the first section of this paper we briefly introduced an up-to-date account of actual visions regarding Altshuller's laws. His original idea was to look at problems from the engineering point of view, starting from technical observations and needs. He first of all considered it his goal to provide the world of inventors with techniques and tools, and decided that these techniques and tools had to be supported by methods. But to be efficient, these methods and tools also had to be built upon a reliable and statistically relevant amount of observations, analyses and tests in real practice accompanied by a measurement of their effectiveness. Later (in the early 1970s), after several iterations of tools and method versions, the statement which emerged logically was that a theory had to be disclosed as the foundation of Inventive Problem Solving.

For industrialists today, there is an urgent need to efficiently operate inventive practice in design and also in the R&D department. This paper is a proposal for experimenting with TRIZ in a way different from that currently practised in consulting areas, since our contribution suggests new options as to how an engineering design project could restructure its early stages. This restructuring aims at the prioritization of problems (here: reduced to contradictions) being solved in conjunction with Altshuller's laws in a pragmatic manner. As a result, a company may expect less fuzziness in the undertaken design orientations, since all potential directions of design, when dealt with according to our approach, are correlated to objective laws while highlighting the sum of unsolved problems standing in the way of each LESE respectively.

From the educational viewpoint, our approach has been proven relevant in an inventive context, where the necessity of an organizing breakthrough is strongly felt. This induces us to postulate that in terms of industry new findings need to be worked out theoretically to begin with, and subsequently through tests as a second step of our present contribution.

Finally, the approach we have developed is aimed at providing an open framework for discussion. We observed that the evolution hypothesis proved to be helpful in the context of LESE utilization, by increasing the capacity of engineering students to benefit from a more coherent understanding and usability of some TRIZ elements. By attempting to be a link between parameters and LESE, they have also linked MSA and contradictions, and thereby, if on a smaller scale, contributed to provoking a systemic impact on TRIZ itself.

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