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From Altshuller's 76 Standard Solutions to a new Set of 111 Standards

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Abstract

The 76 Standard Solutions were created by G. Altshuller as solutions for common inventive problems. Since they were invented, many authors have attempted to improve them, pointing out some difficulties in applying the standards properly and the need to modify this powerful tool. A new system of 111 Standards is proposed, organizing the information of Altshuller's Standard Solutions according to a simple and rigorous functional approach. Standards are now classified by three Macro-classes which refer to harmful functions, insufficient functions and problem of measurement and detection. Every standard consists of an Action, indicating its functional purpose (such as "blocking" or "deflecting" the harmful action, "concentrate" or "enhance" the insufficient action, etc.) and a Suggestion, representing how you can realize the goal by adding or modifying fields and substances. A comparison between the old and the new system of standards is proposed.

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1. Introduction

The 76 standard solutions are a very powerful tool of the well-known theory of inventive problem solving. They were created by G. Altshuller [1] between 1975 and 1985 as solutions for common inventive problems extracted from the studies of patents. The set of standards directly derives from the laws of technical systems evolution, guiding the synthesis and transformation of these systems by implicitly eliminating technical contradictions [2]. In practice, it is usually used in ARIZ (the algorithm for inventive problem solving) [3] as part of the Substance-field analysis, after the Su-field model has been built and any constraints on the solution have been identified [4].

Although both Su-field model and standard solutions are unquestionably effective tools for innovation, their use has been somewhat limited, especially in companies and Western universities. The reasons are different, starting from the influence of translators' interpretation [5] to the shortcomings of the instruments themselves [6, 7].

Many authors have attempted to fill these gaps, pointing out some difficulties in applying the standards properly and in making them attractive for less experienced users. Therefore, the need to modify this powerful tool arises. Many

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examples from the TRIZ community (such as V. Petrov, V. Souchkov, N. Khomenko, A. Smirnov, I. Belski, Z. Royzen, S. Savransky and others) worked on this path. Some of them defined guidelines or a new classification while others built new methods starting from the standards or joining them with other innovation tools. This paper aims to reformulate and enhance the original system of 76 standard solutions with a new system of 111 standards. It improves ease of use and flexibility, maintaining at least the same number of solutions identified by G. Altshuller in his extensive work of research.

2. Su-Field Analysis

The Substance-Field analysis is a TRIZ methodology composed of a substance-field modeling phase, an abstract solving phase and an interpretation phase [8]. This approach is consistent with the TRIZ way of thinking: it proposes to solve the problem with a high level of abstraction, regardless of the particular technical field and exploiting the knowledge of previous similar problems.

As part of the method, Su-field model is a graphical representation of a technical system. It can be presented through three concepts (see Fig. 1): substance, field, and mutual interaction.

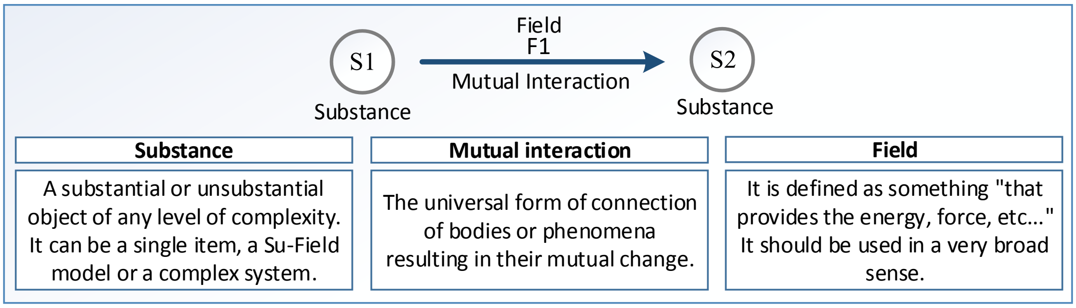

Fig. 1 A part of Su-Field model ontology [8–10].

The original notation of Su-field model is quite different from the notation used in this paper, which reflects the common interpretation of functional analysis and Tool-Object-Product model [11]. Since the Su-field model is used to explain the 76 standard solutions, these differences may lead to some ambiguities. In particular, for the original notation (see Fig. 2 on the left) the dashed line means "action (or interaction) which should be introduced according to the specification of the problem" while the curved line means "unsatisfactory action (or interaction) which according to the specifications of the problem has to be replaced" [9]. Following these definitions, excessive action, insufficient action and harmful action of the functional-analysis notation (see Fig. 2 on the right) seem to be a subclass of the original curved line.

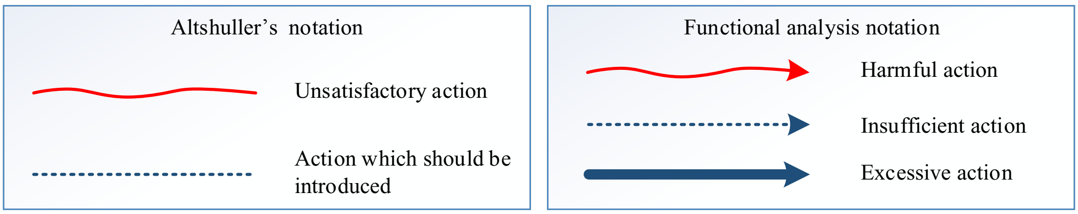

Fig. 2 Original Su-field model notation (on the left) and functional analysis notation (on the right).

More confusion arises on the definition of a substance-field triad (or complete Su-Field). In the original concept of triad Altshuller depicted a field and two substances but he also implied a second field for the mutual interaction between the two substances. In fact, an example from [9] shows a wedging device for cladding consisting of a wedge

S1 and a wedge cladding S2 designed to facilitate the removal of the wedge; the wedge is made in two parts, one of which is easily melted. The heat field F1 acts on S2 by altering the mechanical interaction F2 between S1 and S2. According to Altshuller's approach mutual interaction between substances is indicated without detailing the form of mutual interaction (see Fig. 3).

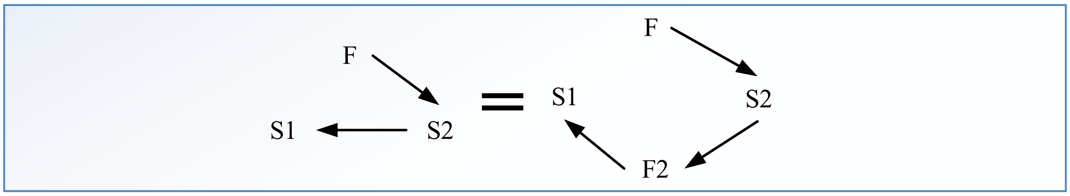

Fig. 3 Altshuller's triad notation [9].

In this way he focused on the field that could be directly controlled, without mentioning how to generate it. In the last decade, some TRIZ experts have used the Su-field triad in a way more congruent to functional analysis [10, 12], using the field F1 as the one between the substances (see Fig. 1). In this paper, the adopted notation is similar to the one of functional analysis, but the interpretation of the original standards has taken into account both points of view.

3. Discussion on Altshuller's Standard Solutions

The first five standards were developed in 1975 by G. Altshuller [13]. They were presented with a theoretical explanation without a classification. In approximately two years the number of standards increased from five to ten [9].

A qualitative leap in the development of standards can be identified in 1979, when a system of 28 standards was published [14]. The system consisted of three classes: standards to change systems; standards for detection and measurement; standards for the use of standards.

A second significant improvement in 1981 led the number of inventive standards to 50, preserving the same three classes but arranging the subclasses in a more logical way. Meanwhile, the current system of numbering was adopted, moving from sequential to structured. The system was organized in three digits: the number of the class, the number of the subclass and the number of the standard for each subclass. The number of classes was not changed until 1985, when the current system of 76 standard solutions was presented [1]. It is structured in five classes [2]:

1. Composition and decomposition of SFMs
2. Evolution of SFMs
3. Transitions to supersystem and microlevel
4. Measurement and detection standards
5. Helpers

3.1. Criticisms and improvement after G. Altshuller

Since 1985, the system of standards was criticized from the TRIZ community and some shortcomings were highlighted. The structure of the standards with five classes complicates their use and appears less logical than the system with just three classes [7, 13]. Many standards are equal to the trends of technique evolution, but they are not a consequence of all the laws of system development [6, 13]. The system of standards is not applied in all fields of the known physical, chemical, biological and geometrical effects [13] and is difficult to expand. It is inhomogeneous [6]: some standards consist in a special case of more general standards leading to frequent repetition. In particular, too much attention is given to the introduction of a magnetic field, which is a special case of the introduction of a field. Most standards can be modeled with Su-Field model, but some of them are beyond the scope of symbolic description of Su-Field. Besides, the formulation and structure of various standards are different and inconsistent. Finally, this kind of classification is not always suitable to guide the choice of the proper standard for a specific problem. A new classification should use the classes to identify the problem instead of classifying the type of solution.

Starting from these assumptions, a great effort has been made in order to improve the system of 76 standard solutions. The problem has been addressed in several ways from a lot of TRIZ experts. At first, some guidelines in the form of flowcharts were developed to facilitate the use of the standards in general or particular situations [15, 16]. Afterwards, some more radical proposals were made. For instance, V. Petrov has worked on a system of generalized models [17], by interpreting the standards as the mechanisms of the laws of evolution of systems. Other authors [7, 18, 19] have generated their own set of compacted standards. In particular, they reduced the number of standards as well as the number of classes, which became three: improving the system with little or no change; improving the system by changing the solution; detection and measurement. Ogot also suggested a different modeling tool: the Energy-Material-Signal model [20].

In order to replace the ineffective numbering, Kim has suggested a new notation to represent both problematic situation and solutions [21].

Meanwhile, Gadd [12] has worked on the reformulation and reclassification of the standards in three classes: harm 24 solutions; insufficiency 35 solutions; measurement 17 solutions. In a similar way, Mann [22] has proposed four classes of standards: incomplete Su-Field; measurement/detection problem; harmful effect; insufficient/excessive relationship.

All the aforementioned proposals are very effective improvements of the classical classification and formulation of the standards, however, some of them strayed far from the original Altshuller's idea. They reduced the strong link between standards and Su-field model, which was part of the greatest Altshuller's discovery [23]. Besides, in order to simplify the use of the standards, they reduced the amount of information they contained or the flexibility of this innovation tool.

3.2. Information on the Standard solutions

From an analysis of the standards we can observe that they contain information to perform both problem description and problem solving. The part of problem description defines a generic problem in terms of objectives, constraints and initial conditions while the part of problem solving contains suggestions for the solution. The information can be found in form of text or graphical Su-Field. All this information is structured in the original system of standards (see Fig. 4).

A standard can be identified with its class, subclass and body. With the exception of the class "measurement and detection standards", all classes and subclasses are named according to the type of solution they lead. So, they can be considered as textual suggestions for the solution.

The body of a standard contains a first condition to identify objectives and/or initial conditions. A second condition and eventually a third one are used to identify constraints of the problem. The rest of the body contains suggestions for the solution, objectives, a graphical representation of initial Su-Field and solution Su-Field model and some examples.

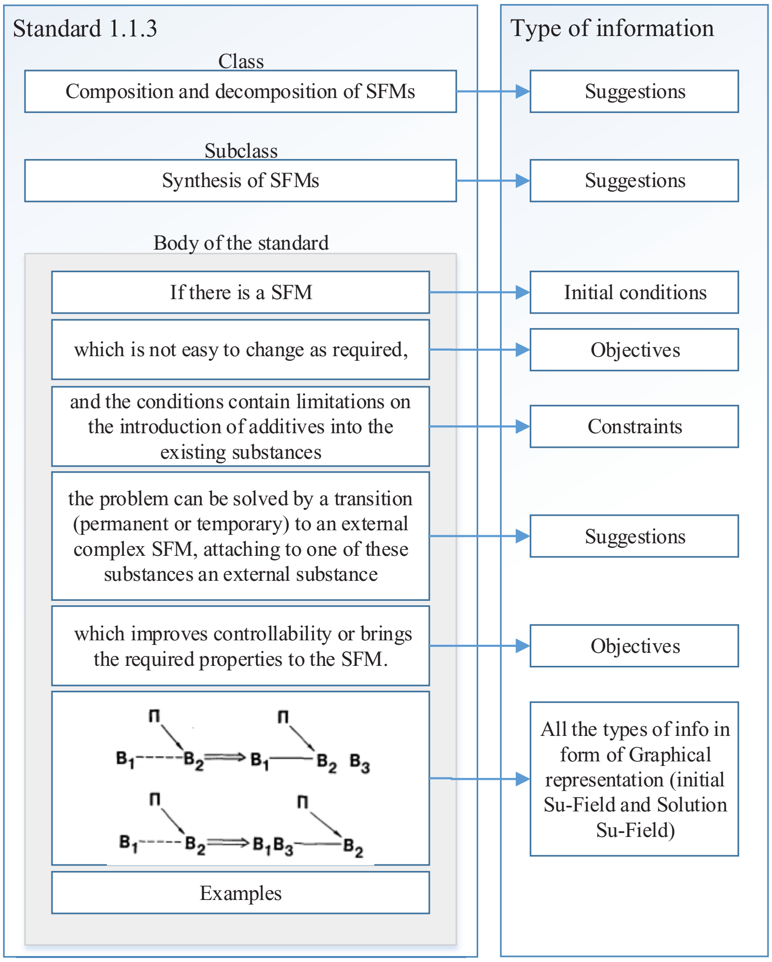

Fig. 4 Type of information in the standard 1.1.3 of the original system of standard solutions.

The information contained in the standards is fragmented and complicated. Consequently, interpretation and reading of a standard are difficult. The use of a standard is given according to the initial conditions, which are expressed as if <condition> then. This approach is inefficient and tedious. In fact, many authors have proposed approaches to simplify the application of standards, proposing an external schema based on a functional diagram [24]. However, many difficulties have been reported to organize all the information contained in the original system and to manage the correct use of the class “Helpers”.

4. Proposal: a new classification for the standard solutions

The new proposed classification seeks to strengthen the relationship between Su-field model and standard solutions. It aims to improve flexibility and ease of use, preserving all the paths to find a solution and the other information (constraints, conditions, etc.) contained in the original standard solutions.

It follows an intuitive functional approach and it is composed of three macro classes:

I: Standards for insufficient and missing actions (49 standards divided into 6 Actions);
H: Standards for harmful and excessive actions (49 standards divided into 6 Actions);
M: Standards for measurement and detection (13 standards).

All the standards have a well-defined structure. The first part is the Action. It consists of the verb and the object and identifies the path for the solution. For instance, to eliminate a harmful action you can block it, deflect it, make the Tool unable to produce it, etc.

The second part, called “Suggestions” contains a hint which specifies the change on the Su-Field model to achieve the Action. For instance, in order to block a harmful action you can add a substance between Tool and Object, this substance can be found in the system or in the external environment, it can be added permanently or temporarily, etc. Suggestions contain hints from the whole old system of standards, “Helpers” included.

Every standard is composed of one Action and one Suggestion.

In order to simplify the management of the standards, the Suggestions have been grouped into four “Clouds”:
S^+: Add substances (3 suggestions);
F^+: Add fields (3 suggestions);
S’: Modify substances (12 suggestions);
F’: Modify fields (5 suggestions).

These “Clouds” can be recalled when needed and contain guidelines to modify a generic Su-Field model. In this sense, an Action can be linked to one or more clouds, forming a whole subclass of standards (see Fig. 5).

This structure combines simplicity and completeness without overloading the system. The user has a comprehensive overview of the feasible Actions and he/she can choose the most appropriate path to solve the problem. Moreover, he/she can deepen the suggestions, referring to the specific cloud.

4.1. The new classes of standards

The class “Standards for insufficient and missing actions“ (I) and the class “Standards for harmful and excessive actions” (H) are designed to approach a generic problem of unsatisfactory action. This classification has been studied to enter the system of standards directly, once the problematic situation has been identified as an insufficient action, a missing action, an excessive action or a harmful action.

A novelty lies in the definition of how to intervene on the problem in term of verbs, such as “to block”, “to deflect”, etc. Moving from harmful actions to insufficient actions, the verb changes together with the purpose: “to block”

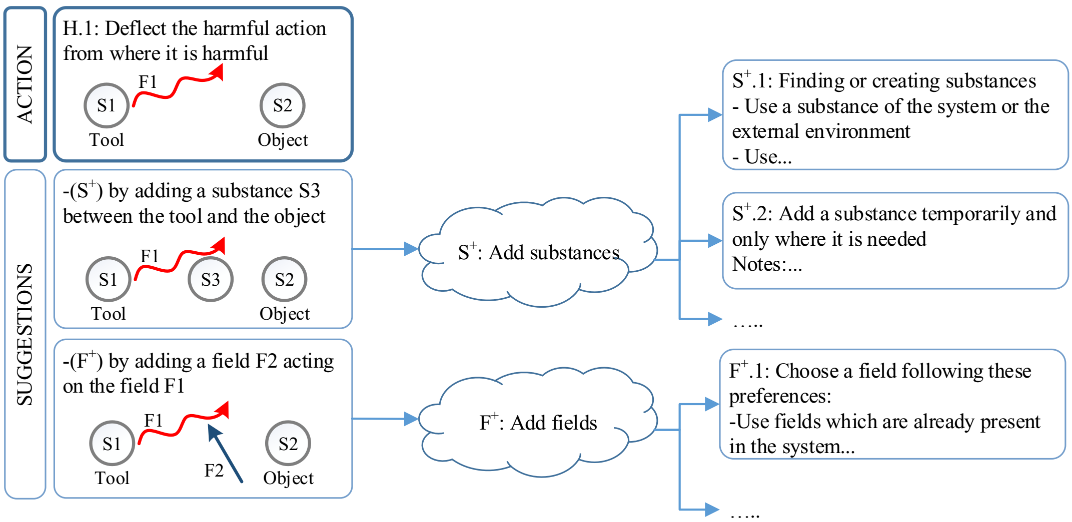

Fig. 5 The use of "clouds" to regroup the standards (subclass H.1).

Harmful and excessive actions are addressed in the same way because they share the same purpose of reducing the effect of an action. A similar consideration can be made for insufficient and missing actions, which share the goal of improving the effect of an action. However, the class I also covers problems of controllability, efficiency and difficulties in obtaining a product, i.e. problems with more generic lacks.

Both classes are defined by a set of six actions, which are shown in Fig. 6. They allow the user to have an overall overview on the paths for the solution. In addition, they are extended by recalling the specific "Cloud". The creative process and the interpretation of an Action are supported by a graphical representation of the solution.

In literature, the class for measurement and detection of the original system of standards is probably the less criticized by the TRIZ community. It is a well-organized set of standards. For this reason the new class "Standards for measurement and detection" (M) is very similar to the original one. However, although the order has been maintained, the structure of each standard has been adapted to be composed of one Action and one Suggestion, without subclasses. For instance, the information contained in the original standard 4.2.2 ("If a system (or its part) does not provide detection or measurement, the problem is solved by transition to an internal or external complex measuring SFM, introducing easily detectable additives") can be found in the new standard M.5 ("Make the object easily detectable - by introducing easily detectable additives").

4.2. A practical example to use the new set of standards

In the context of industrial circuit breakers, a pin is used to instantaneously stop the movement of an arm (which is a part of a mechanism). Given the stresses of the impact the pin can break, ceasing to perform its function. A solution is required to avoid breakage of the pin.

The Su-Field model of the problematic situation can be depicted as an arm acting with a harmful action ("breaks") on a pin. Since the action is harmful, the class H can be used. Thus, referring to Fig. 6 on the left we can read the six Actions which may solve the problem. Some solutions arise easily without the help of any Suggestion, for instance:

becomes "to enhance", "to deflect" becomes "to concentrate", etc. Thus, there is a logical symmetry between the Actions of class H and class I.

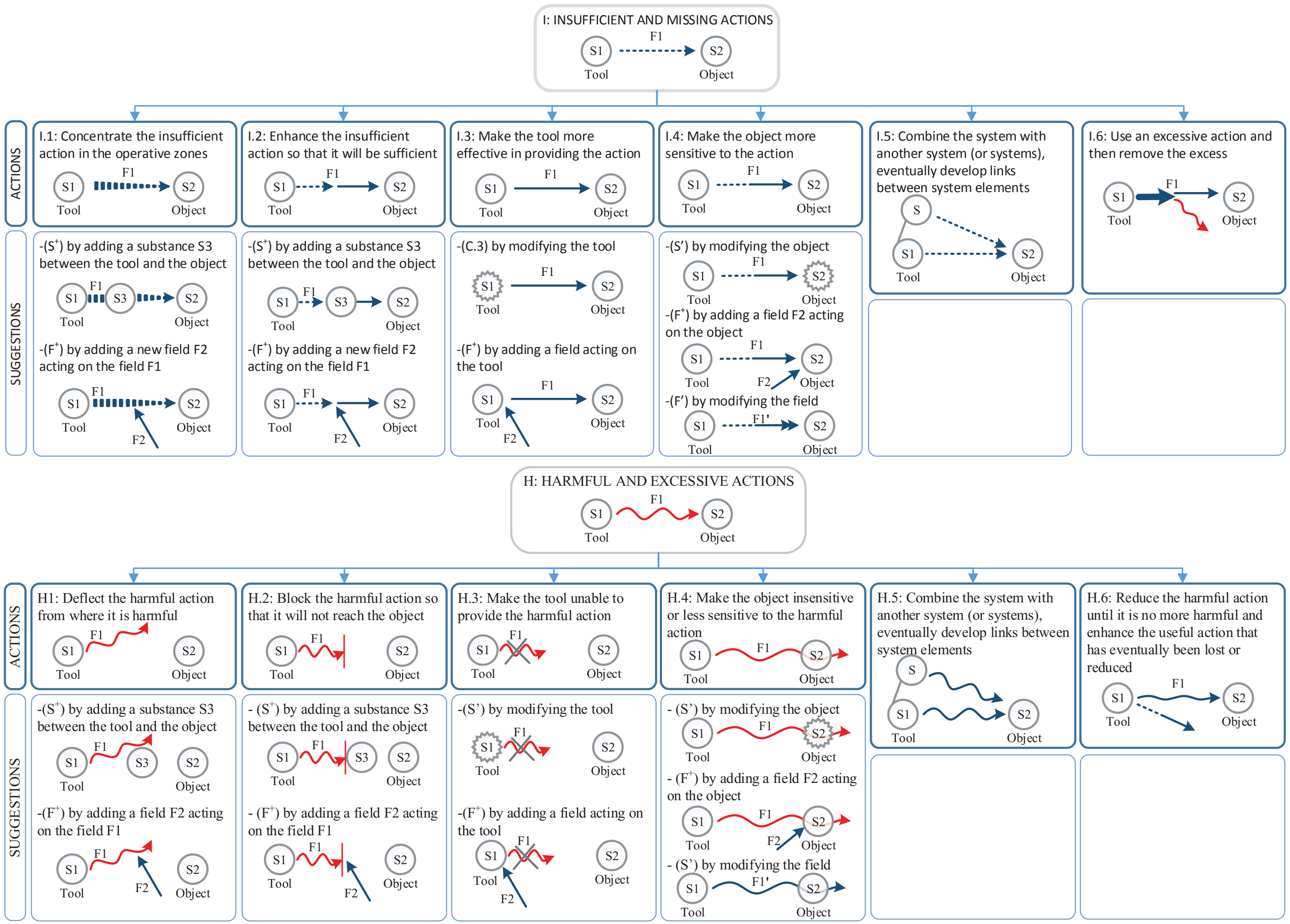

Fig. 6 Actions for problems of harmful actions (on the left) and insufficient actions (on the right).

- H.1->The harmful action can be deflected on another element (a sacrificial/alternative element). Thus, the pin will perform its function only if the element breaks.
- H.2->The harmful action can be blocked by a substance between the arm and the pin. The substance should distribute the impact.
- H.3->The arm can be modified so that it will not break the pin. The arm could be designed to reduce the impact.

These solutions are very abstracted and they should be elaborated to find more concrete outcomes. Currently, there are no effective methods to choose the best solution to be deepened in this phase. However, it can be useful to evaluate the solutions intuitively, considering constraints of the problem and more general considerations.

In this example, we investigate the third path for the solution, which has been found from the Action H.3. Thus, we browse the Suggestions (organized in Clouds) in order to lead to more specific solutions.

Reading the Suggestions related to "(S') by modifying the tool" we found a useful hint about the use of flexible materials: "S'.6: Increase the degree of dynamics of the substance by a transition to a more flexible, rapidly changing structure of the system. Notes: Making a substance dynamic starts with dividing it into two joint-coupled parts and continues along the following line: One joint –-> many joints –-> flexible object". This suggestion leads to an arm with a flexible part or a joint. Similarly, reading the Suggestions related to "(F+) by adding a field acting on the tool" we found another useful hint: "F+.2: Consider fields with high level of controllability, such as a magnetic or an electric field". This suggestion leads to an arm slowed by a magnetic field. The solution to this problem may be, for example, the use of both these solutions at the same time, i.e. an arm with a flexible part, slowed by a magnetic field before impacting on the pin.

Ultimately, the Actions are useful to identify the possible solutions in a very abstract way. Then, after some consideration, the user can decide if the solutions must be expanded with more detail, following the hints contained in the Suggestions. Although the number of standards is increased from 76 to 111, they are grouped in only 25 Actions ensuring completeness and simplicity at the same time. The Actions allow a fast overall overview of the possible path to find a solution. Only if needed, the user can refer to more detailed suggestions by reading the Clouds.

5. Comparison

The 111 standard solutions are designed by organizing the information contained inside Altshuller's standard solutions. Thus, all the 76 standard solutions (except one) are included in a new system of standards.

The original system of standards often provides a suggestion for only a type of problem. The new system splits a suggestion according to the purpose of the problem, reformulating the hints using different verbal forms. For instance, the original standard 1.2.1 is defined for a harmful action, while in the new standards we also suggest to use it for insufficient action. So, if a substance can be used "to block" an action, a substance can also be used "to enhance" it (amplifier).

Some hints of the old set of standards are merged together following similarity of meaning. For instance, suggestions such as "introducing a substance which is a modification of the present substances" (1.2.2) and "introducing the external environment as substance" (1.1.4) are part of a more general new Suggestion "Finding and creating substances".

Some old standards which provide very specific suggestions have been included in the new system in form of examples or notes in order to uniform the validity level of standards and reach more homogeneous suggestions. For example, standards of the 2.4 subclass refer to the use of ferromagnetic substances and ferromagnetic fields which are obviously too specific recommendations to be maintained as general paths for the solution.

In Altshuller's standard solutions the user is supposed to take into account all the constraints from the beginning. The use of a standard is closely related to the conditions of applicability of the standard itself (if <condition> then). In this way, the user needs to browse the entire system of standards finding the most suitable suggestion to solve his problem.

In the new proposed system of standards, the conditions on the constraints are removed. In particular, the classification itself replaces the conditions. The user enters the system of standard according to the functional model of his/her problem and refers directly to the proper set of standards. A study of the correspondence between the old and new standards ensures the presence of all the information from the original standards. The only exception is the standard 1.1.1. This standard suggests the creation of a new function and do not fit with the new system of standards. For this type of problem, several whole methodologies were developed [25].

6. Conclusions

In this paper, a new system of 111 inventive standards is proposed. It has been conceived from a thorough analysis of the information contained in the Altshuller's 76 standard solutions.

The new system simplifies the use of a standard, making it more congenial to a functional approach and more attractive for less experienced people.

It divides the structure of a standard in an Action and a Suggestion. Thus, it is no more necessary to read the entire set of standards to overcome a problem. In fact, very often a solution is found just by checking the verbal form of the Action instead of reading the full standard, therefore saving time and effort.

New paths to find the solution are pointed out through the new organization of the standards. They have been derived by testing the same hints of the old standard solutions matched with different objectives and they help in completing the system of standards.

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