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How to exploit Standard Solutions in problem definition

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Abstract

In this paper we propose a creative method to support ARIZ, a step-by-step method for problem solving invented by Altshuller in 1956. Specifically, we propose a new formulation of step zero, which deals with clarifying and verifying the problem statement. Since the birth of ARIZ, step zero has been continuously updated; ARIZ-56, ARIZ-59, ARIZ-61, ARIZ-64, ARIZ-65, ARIZ-68, ARIZ-71,ARIZ-75, ARIZ-77, ARIZ-82, and 3 versions of ARIZ-85 prove all attempts to balance convergent and divergent phases in order to change the perspective on the given problem, adding useful information from the market or the patents, igniting lateral thinking and overcoming psychological inertia. After Altshuller's death, ARIZ development has been continued by TRIZ masters and followers without establishing a reference model.

This paper proposes a revision of two classical Altshuller's tools, the "multiscreen method" and "76 standard solutions" to be used in the problem formulation phase. The first one is called Film MakerTM and is a simple tool to manage the cause-effect relationship through the description of a film, i.e. a sequence of events. The second one is called "111 Standards" and is a structured elaboration of Altshuller's 76 standard solutions to systematically identify alternative partial solutions. A four step method containing these tools is presented together with an exemplary case.

After more than 2 years experimentation within a project commissioned by the chamber of commerce of Bergamo, involving over than 30 companies, we discuss the results and efficacy of this approach

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1. Introduction

As Bransford [1993] argues, “The ability to identify the general problem and generate the sub problems to be solved is crucial for real-world problem solving” [1]. Problem formulation [or problem definition] is of unquestionable importance inside a problem solving activity. Real world problems are not pre-defined and the solver must examine the context from which the problem emerged and determine what the nature of the problem is [2].

The problem formulation phase influences the outcomes of a problem solving activity, i.e. once a specific representation of the problem is developed, a particular solution will follow from that representation [3]. Contextually, the importance of problem formulation on achieving original and creative solutions has been stated by several other authors [4–8].

Jonassen [1997] suggested to preempt the possible problem solutions Generation with two processes [2]:

- Articulation of problem space and contextual constraints.
- Identification and clarification of alternative opinions, positions, and perspectives of stakeholders.

The road to solutions requires creativity for working in a complex and dynamic system in which there are more “messes” than neat problems [9, 10].

Overall, problem formulation involves the understanding of the problem, the identification of a problem representation, and a reduction of complex ill-defined problems into many clearer well-defined problems.

The goal of this paper is to support problem formulation with a tool for widening the perspective on the problem, obtaining several alternative formulations. Furthermore, with this paper, the authors recognize the effectiveness of a problem formulation in form of contradiction and promote the use of ARIZ-85C [Algorithm for solving inventive problems] for the resolution phase.

Structure of the paper: in section 2 an historical view on the problem formulation in different versions of ARIZ is presented. Section 3 introduces the state of the art about the 111 Standards. In section 4, a description of a new structured method to support ARIZ-85C during step 0 is presented. In section 5, the paper shows the contextual framework of this research and the relationships with local companies. Eventually, section 6 explains conclusions and limits of the presented methodology.

Nomenclature

TRIZ	Theory of Inventive problem solving
ARIZ	Algorithm for Inventive Problem Solving
TOP	Tool-Object-Product

2. State of the art: Problem formulation in ARIZ

In the diverse word of TRIZ, the formulation of the problem is a topic of fundamental importance. The quotation by John Dewey "a problem properly defined is virtually solved” [11] is often cited and universally shared. However, it is still an open issue, and ARIZ is the demonstration of that. In fact, in ARIZ, the most representative and acknowledged tool of the TRIZ theory, the step 0 dedicated to the problem reformulation has been modified many times until its final elimination.

The first version of ARIZ dates back to 1956, but only in the 1964 version a section devoted to "Clarifying and verifying the problem statement” appeared. It remained unchanged until 1968, when the section related to problem analysis was expanded and supported by techniques for overcoming psychological barriers (Size Time Cost - STC tool, etc.). In this version the correct problem identification was almost half of the entire algorithm.

The versions belonging to the 1970s (ARIZ 71, ARIZ 75, ARIZ 77) had the problem formulation and analysis phases as large and distinct, until obtaining the 1977 version, by successive and gradual changes. ARIZ 77 was based on a single step composed of nine sub-sections, including techniques for reducing psychological inertia, comparison techniques based on existing systems on the market and patents knowledge.

In the following versions (82-A, B, C, D and 85-A), the problem formulation stage remained unchanged until version 85-B, where it suddenly disappeared.

The section on analysis and reformulation of the problem was eliminated, even though it was considered necessary and useful, because it was probably considered non rigorous compared to the other steps. Also G. Altshuller, the founder and creator of the TRIZ theory, was not able to find a structured procedure for the formulation of the problem.

This lack, in a context of a well-structured and guided theory, could not pass unnoticed and without any consequences. In fact, in following years, many TRIZ specialists have tried to bridge this gap.

Immediately after 1985, the suspension of ARIZ developments by Altshuller and the need for a structured step guiding the formulation of the problem was perceived and thus proposed by many of his collaborators [12].

So further versions of ARIZ, containing a section on the analysis of the problem, were developed (such as ARIZ-KE- 89/90, ARIZ-SMVA 91, ARIZ92, Ariz.-96SS), up to the first computer programs used to support this phase, such as those made by Ideation, Invention Machine and Iwint [13–15], which help and try to guide the user to the first phase of problem approaching, consisting of information collection and problem formulation.

3. State of the art: The 76 standard Solutions and their evolution into 111 standards

Problem formulation also involves building a body of knowledge about the problem area. "How much someone knows about a domain is important to understand the problem and generate solutions" [10]. In order to provide external knowledge, or just to trigger designer's creativity, several sources of knowledge can be used, such as web searches, patent searches, physical effects databases or guidelines.

The 76 standard solutions are a very powerful tool of the well-known theory of inventive problem solving. They were created by G. Altshuller [16] 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 [17]. In practice, it is used in ARIZ (the algorithm for inventive problem solving) [18] as part of the Substance-field analysis, after the Su-field model has been built and any constraints on the solution have been identified [19].

Since they were invented, many authors have attempted to improve them (also recently [20, 21]), pointing out some difficulties in applying the standards properly and the need to modify them.

A new system of 111 Standards was presented in the TRIZ Future Conference 2013 [22], organizing the information of Altshuller's Standard Solutions according to a simple and rigorous functional approach. Standards are now classified in Macro-classes which refer to harmful functions, insufficient functions and problems of measurement and detection. Accordingly, the use of Tool-Object-Product model [23] provides a graphical representation of this classification. 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. Furthermore, Suggestions have been grouped into General and Specific Suggestions to manage a big amount of hints [22].

During the last year, although the set of 111 Standards has preserved its name, it has been expanded and completed. A software version has been developed [24] and a first evaluation has been performed on its effects on creativity outcomes.

The 111 Standards were initially presented to improve the phase of solution generations, but their functional structure is also suited for the problem formulation phase, so as to divide the problem into alternative sub-problems to be solved.

4. Proposal: problem formulation through Film Maker™ and the 111 Standards

A comprehensive strategy for ARIZ step 0 has been developed after ten years of studies and testing with ARIZ-85C with companies. Step 0 is composed of a set of strategies and tools for "calling to question" the given problem. For the sake of brevity only one of this strategies are taken into account.

Thus, starting from the perceived problem, the proposed methodology follows a step by step procedure to widen the perspectives on the current situation and support a systematic generation of solutions and partial solutions. Afterwards, it helps the formulation of a technical contradiction and suggests the use of ARIZ-85C to overcome it.

This methodology is composed of four steps and its schema is shown in Fig. 1.

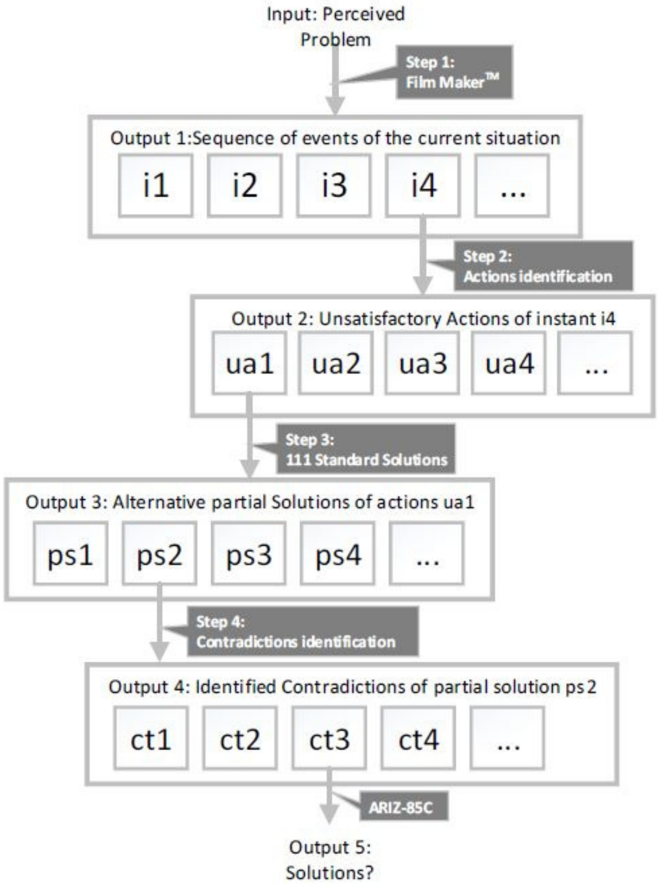

Fig. 1. An overall schema of the proposed step by step methodology. step by step methodology

Each step is supported by the corresponding tool:

1. *Film Maker*™ [§4.1]: build a Film Maker™ about the problem, describing a sequence of instants [i1, i2, …].
2. *Actions identification* [§4.2]: identify one or more unsatisfactory actions for one or more selected frames (ua1, au2, …).
3. *111 Standards* [§4.3]: generate alternative partial solutions, with the 111 standards, for one or more selected unsatisfactory action (ps1, ps2, …).
4. *Contradictions identification* [§4.4]: check for drawbacks about one or more selected partial solution and define contradictions (ct1, ct2, …). Use ARIZ-85C to overcome them.

In the following sections, the aforementioned tools are explained in detail to allow an easy reproduction of the entire methodology.

4.1. Film Maker™

The Film Maker™ tool is used to describe the dynamics of the current situation, representing the complexity of the problem as a sequence of events.

This tool is studied to highlight the cause-effect relationships that involve time, is composed of a sequence of states and are represented in frames on a time axis. In this sense, each state represents a picture of what is happening in a specific instant of time.

A frame (or instant) is divided into an upper part and a lower part. The first one specifies the effect of the actions which has been described in the previous frame. The second one describes the actions between elements on the current instant.

Usually, a Film Maker™ is completed starting from the instants where the problem solver has his own perception of the problem. Afterwards, new frames are added in the past and in the future in order to create a film. Each frame should contain an image or a drawing and/or a textual description.

In figure 2, the perceived problem “I cut the weeds of my garden with a sickle, but the sickle rapidly wear” has been analysed with this tool.

The first two frames will be a representation of the perceived problem, which has to be placed in a certain instant of time. First, we write about the current interactions in the bottom part of a frame, then, moving into the upper part of the next frame we write the effect of the previous interactions (see Fig. 2).

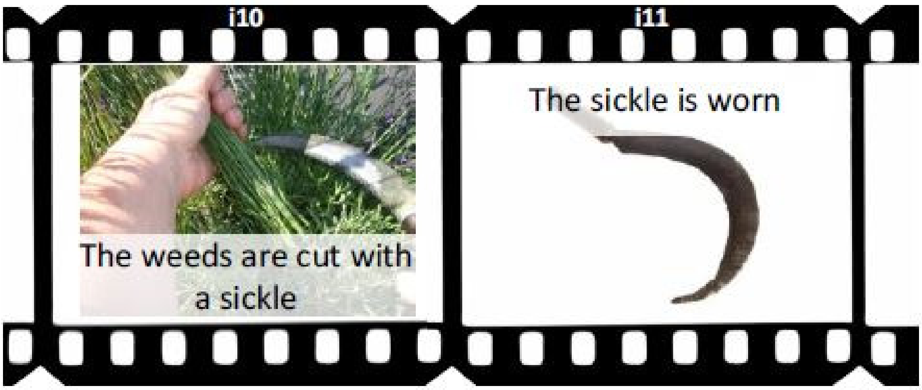

Fig. 2. Film Maker™: the representation of the perceived problem in frames.

Now that the perceived problem has been described, we can fill the frames in the past and in the future. Thus, before “the weeds are cut with a sickle” the weeds must grow; in order to grow, the weeds must be fed from the ground, they must be exposed to the sun etc… In Fig. 3 not all the conditions are mentioned for simplicity of representation.

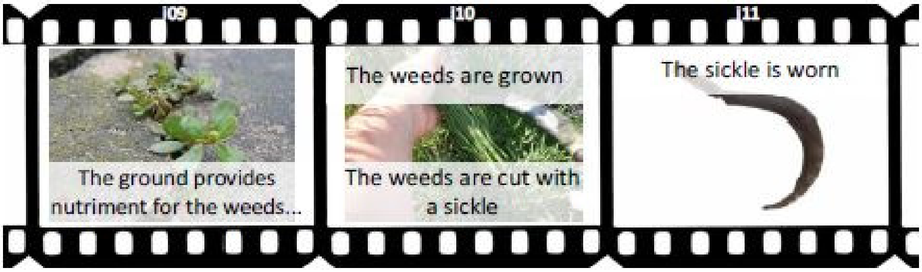

Fig. 3. Film Maker™: filling the past and the future frames.

Moving again toward the past, the weeds were seeds, and seeds should be transported by the wind and so on. The same concept can be applied into the future, where the sickle blade has been sharpened, polished and so on.

The output of this tool is a sequence of frames with the aforementioned structure. From practical experience, a completed Film MakerTM should contain at least seven frames, highlighting every state in which a condition is changed.

The Film MakerTM has some similarities with the known TRIZ tool called Multiscreen [25], but it has just one row and its purpose is quite different. Multiscreen (or 9 windows) itself has been used in some different ways from other authors [26], but in this sense, a Film MakerTM is more similar to the Domino Theory [27] where a long series of events can result in an unexpected situation.

4.2. Actions identification

Thanks to a completed Film MakerTM, the user has a comprehensive overview on the changing conditions in time, and he can choose the most appropriate moment to intervene.

In this step, the user is invited to choose a specific frame where an unsatisfactory product is present. Then, considering the bottom part of the previous frame, he must relate the unsatisfactory product with one or more unsatisfactory actions. Thus, the relationships must be formalized in the form of a problematic TOP model: the <tool> acts on the <object>, obtaining a <product>. There are three types of unsatisfactory actions that can be used for this purpose, and they are shown in Fig. 4-6.

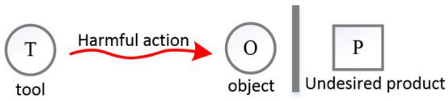

Fig. 4. TOP model for harmful actions.

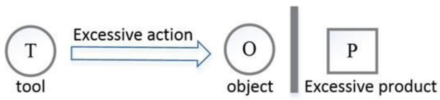

Fig. 5. TOP model for excessive actions.

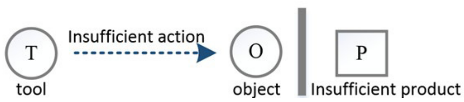

Fig. 6. TOP model for insufficient actions.

Completing the example of section 4.1, we choose the frame where the weeds are grown; thus, the unsatisfactory product is “the grown weeds”. Therefore, we search the previous frame to find unsatisfactory actions, which lead to this product using available resources in that moment (see Fig. 7):

1. The ground feeds the weeds, obtaining grown weeds.
5. The sun provides energy for the weeds, obtaining grown weeds.
6. The sun heats insufficiently the weeds, obtaining grown weeds [insufficiently burned].
7. …

The output of this step will be a list of sub-problems, in the form of TOP models, related to a specific couple of frames.

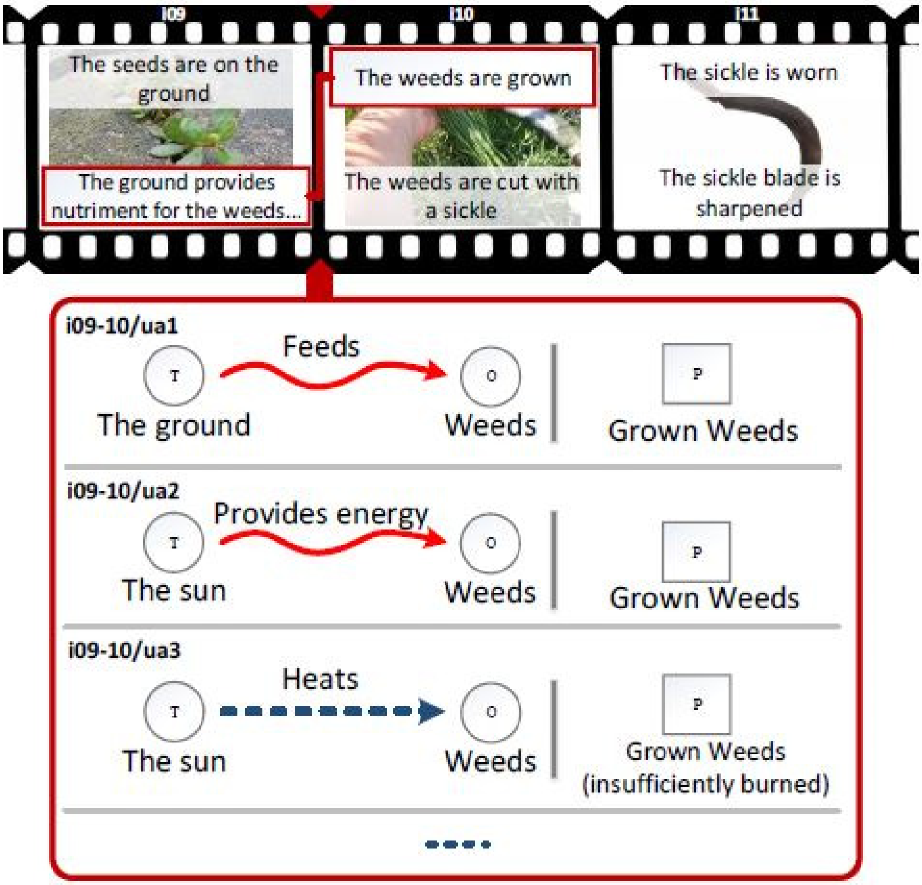

Fig. 7. Actions Identification: the problematic TOP models for a selected couple of frames.

4.3. The 111 standards

After the problematic TOP models of a specific instant have been represented, the user must select one of them and solve it with the help of the 111 Standards.

The set of 111 standards has been developed to systematically provide several ways to solve a problem. A standard has a structure which comprises 5 parts:

1. Identification of the problem: the first part of the guideline is a description of the problem in form of TOP model.
8. A Sub-goal (or Actions): they are conceptual solution to the identified problem.

9. A General Suggestion: they are trigger to reach the selected Sub-goal.
10. A Specific Suggestion: they provide different ways to follow a General Suggestion.
11. An example

For each problem there are several Sub-goals, for each Sub-goal there are several General Suggestions and so on.

The main idea on the use of these guidelines is that the user may just read the Sub-goals, and use the Suggestions and examples only if needed.

Completing the aforementioned example, we choose to solve the second problematic TOP model, in which "the sun provides energy for the weeds, obtaining grown weeds". This is a problem of harmful action, thus, the sub-goals automatically generated by the 111 standards are as follows (see Fig. 8):

1. Deflect the action "to provide energy" from where it is harmful.
2. Block the action "to provides energy" so that it will not reach the weeds.
3. Make the sun unable to provide the harmful action "to provide energy".
4. Make the weeds insensitive or less sensitive to the harmful action "to provide energy".
5. Make the "grown weeds" useful or not harmful.

Although the third Sub-goal is not reasonable, the other ones are description of different kind of solution. Deepening the second sub-goal, the description of the solution can be more detailed. The 111 standards can provide a General Suggestion, so that the description becomes: block the action "to provides energy" so that it will not reach the weeds, by adding a substance between the sun and the weeds. Thus, a partial solution to this problem can be a simple roof, which avoids the sunlight to reach the weeds.

The output of this step is a series of partial solutions that solve the identified problematic TOP model.

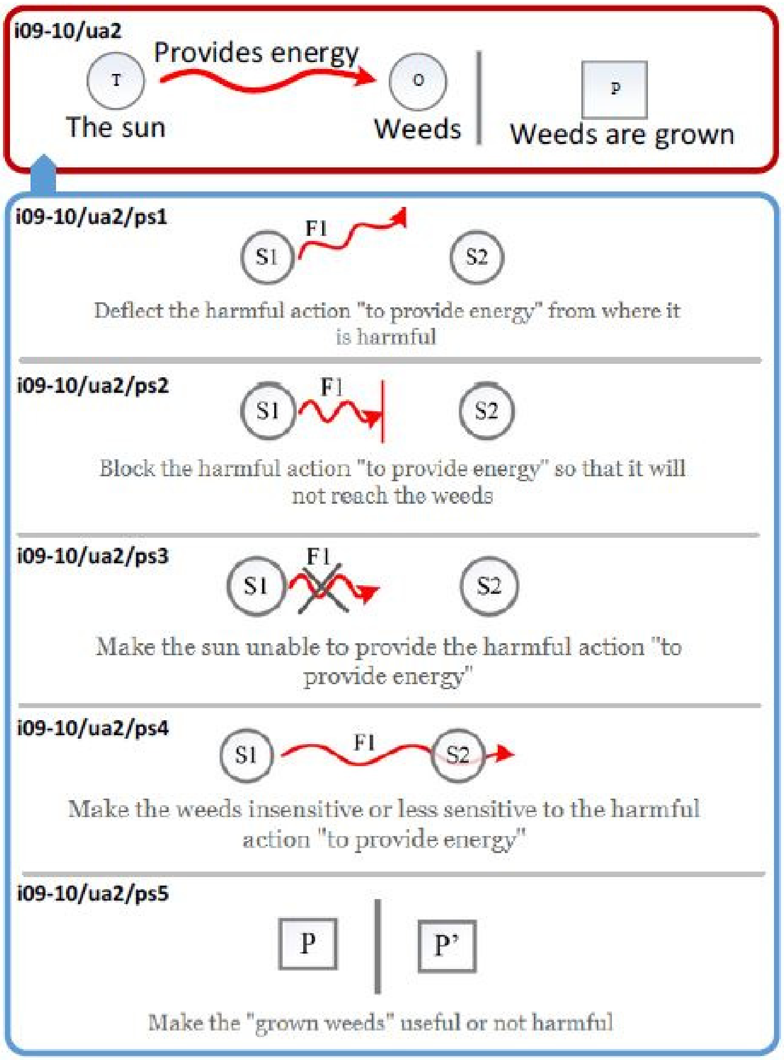

Fig. 8. The 111 Standards: automatically generated sub-goals for a selected problematic TOP model.

4.4. Contradictions identification

After the solutions of a specific TOP model are defined, the user must choose one of them and evaluate it. The chosen partial solution solves the perceived problem, which was the input of the entire methodology; however, other problems will probably arise.

The contradictions identification phase is the more creative one. Inside it, the user must imagine the selected solution and find drawbacks in its implementation. If necessary, he should define a new Film MakerTM to describe the dynamics of the new solution, but it is usually enough to answer the following questions:

1. Compared to the current situation, does the new solution involve new unsatisfactory products?
2. Compared to the current situation, does the new solution involve new harmful actions?
3. Compared to the current situation, does the new solution involve new undesired consequences?

If one or more drawbacks are identified, we can formulate a technical contradiction. Specifically, ARIZ presents the formulation of a technical contradiction as follows:

A technical system for <state the purpose of the system> includes <list the main parts of the system>.

Technical contradiction 1 (TC-1): [identify]. Technical contradiction 2 (TC-2): [identify].

It is necessary, with minimum changes to the system, to

<state the required result>.

In accordance with the proposed methodology, TC-1 will describe the current situation, while TC-2 will describe the new generated system. Furthermore, the understanding of the dynamics of the problem can result in a more aware compilation of <purpose of the system>, <main parts of the system>, as well as <the required result>.

Completing the example of the previous paragraphs, we answer the first aforementioned questions with: yes, the new solution “prevents the sun to provide energy for plants to grow”. Therefore, a contradiction can be defined as:

A technical system for “growing plants” includes “plants, weeds, ground, sun”.

Technical contradiction 1 (TC-1): without using a roof to block the sun, the plants grow, but the weeds infest the ground.

Technical contradiction 2 (TC-2): using a roof to block the sun, the weed does not grow, but the plants do not grow too.

It is necessary, with minimum changes to the system, to prevent the weeds to grow, allowing the plants to grow.

A graphical representation of this contradiction is shown in Fig. 9.

Here, the proposed methodology suggests the use of ARIZ- 85C to overcome the technical contradiction. Since ARIZ- 85C is a relatively mature and known methodology, we will not describe it and we will present just one of the solutions that can arise from separating in space the presence of the roof. Thus, completing the example of the previous paragraph, the most interesting solution, found with ARIZ-85C, has been a special configuration of plants in order to block the sun from reaching the weeds. This solution is depicted in Fig. 10, where plants themselves grow in such a way that they make a roof to block the sunlight, preventing the weeds to grow.

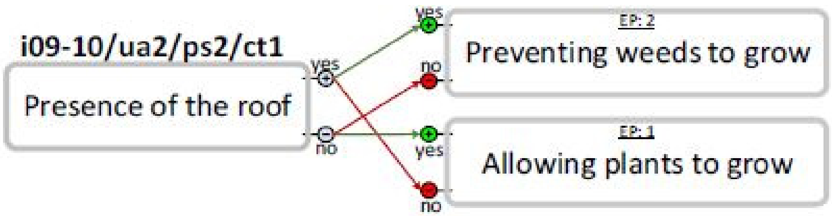

Fig. 9. Contradictions identification: the representation of a contradiction for a selected partial solution [i09-10/ua2/ps2/ct1].

Fig. 10. A solution for an identified contradiction. A roof which is made of plants with grapes that get the sunlight and shade the ground.

Finally, the output of these last two steps is respectively composed of one or more contradictions and one or more solutions for each contradiction.

5. Experimentation

This methodology has been applied since 2012 within a set of projects aimed at promoting and strengthening the competitive growth of micro, small and medium Italian enterprises (SMEs). It has been developed for guiding and supporting those that want to experience a structured methodology for the generation and management innovation in companies. The project was promoted and funded by the Italian Ministry of Economic Development and Chamber of Commerce of Bergamo and coordinated by Unioncamere [28, 29].

In almost 2 years, more than 30 companies have been trained in TRIZ by 40 hours of training and 16 hours tutoring, focused on ARIZ and including our ARIZ step zero. Contextually, the 111 Standards software was provided to users and tested on real case studies.

This project has been demonstrating as ARIZ can be an entry level tool if ARIZ step zero is opportunely systematized. Part of creativity, required to assess the problem, can be oriented and helped by the 111 Standards and the Film MakerTM.

Companies push our research in implementing these tools and completing them with new case studies to be used as triggers by analogy.

A similar approach has been conducted with students from mechanical and management engineers of the University of Bergamo. During the course of "Innovation product and process" (8 credits), the methodology has been taught to student, improving their problem solving skills and providing further testing for this research.

6. Conclusions

In this paper, we proposed a creative and systematic method to support ARIZ-85C in clarifying and verifying the problem statement. Specifically, a comprehensive strategy for ARIZ step 0 has been developed after ten years of studies and testing. Step 0 is composed of a set of strategies and tools for "calling to question" the given problem. In this paper, we presented one of these strategies, which has been developed to support the generation of partial solutions and the definition of contradictions. Starting from the perceived problem, it follows a step by step procedure to widen the perspectives on the current situation and support a systematic generation of solutions and partial solutions. Afterwards, it helps the formulation of a technical contradiction and suggests the use of ARIZ-85C to overcome it.

The original TRIZ tools for problem formulation, such as those in ARIZ-77, were used together as methods to reduce psychological inertia and allow a divergent phase. However, the definition of a contradiction has never been entirely structured.

With the proposed methodology, the approach to problem formulation deeply changed. The strategy is structured to systematically manage a divergent phase for the generation of contradictions. The 76 Standard Solutions, which once were just used for the central phases of ARIZ, have been elaborated and transformed into the 111 Standards and are now suited for the problem formulation phase.

What can be easily seen from the application of this method is that solutions are often very far away from the initial perception of the problem; a result that can be associated to the increased understanding of the overall dynamics of the problem.

Since every step of this methodology highlights different paths that can be selected to reach a solution, the main weakness of this approach is the absence of a guided choice of the most prominent path. Consequently, the user may find unsatisfactory solutions following one of the possible paths and he must go back to a previous crossroad, repeating a part of the procedure.

The software implementation on the entire methodology is under development. Instead, a working version of the 111 Standards is available online [24].

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