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Towards the right formulation of a technical problem

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Abstract

Due to the growing interest in innovation issues, support for suitable problem definition is increasingly important and desired, focusing on the identification of the right direction of work without getting lost on useless roads [1]. This work presents a set of rules, conceived by the authors to better define the right reformulation of the initial problem. Most of the philosophical reflections about the concept used to build this procedure are presented. Particular attention is focused on the definition of the exact zone of the critical element to work on, in a specific and precise instant of time. Time and space ontologies, and an historical excursus about operative time, are accompanied by many technical examples in order to provide a deep awareness about classical problem solving steps, already present in ARIZ 85C but used in a different way.

Keywords: TRIZ; Problem reformulation; Psychological inertia; Operative zone; Operative time;

1. Introduction

Any problem solving activity can be divided into two main phases: the definition of the problem to be solved- and the potential solution investigation.

Such phases, widely discussed in literature, are strongly interconnected.

If on one hand, literature offers various problem solving methods, , on the other hand it is not so easy to find a proper tool for the problem statement which, instead, could be really effective in guiding a problem solver during such a delicate phase.

This step is very critical due to psychological barriers derived from traditional modeling and it causes one of the most frequent mistakes made during the problem solving process: finding optimal solutions to wrong problems, with the consequence of leaving the original problem unsolved. This is due to the problem definition phase; in fact the existing methods with related holes are not able to avoid typical problems and errors related to the formulation stage, such as:

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- formulating problems in which subjective evaluations hide and distort the real developments of a problem (often the same problem changes depending on the person who faces it, because it is analyzed only by subjective evaluations, which are often distant from reality);
- formulating problems in which the psychological inertia deviates from the real causes of a problem and from the necessary skills for its solution, leading to limited formulations, which derive exclusively from a personal knowledge and technological background (a chemist will be inclined to see chemical problems, a mechanic mechanic problems, and so on);
- formulating problems at wrong detail levels, regardless of the optimal one required by the solution;
- formulating problems with inappropriate statements for the consecutive phase of solutions generation (formulations by too many specific terms, formulations not containing all the necessary information of the exhaustive problem definition, such as time, space, etc.).

In order to overcome such limits, the authors have worked on a procedure for an unambiguous and objective formulation of the problem, without the influence of psychological inertia or some subjectivity. Such a procedure is called “Bob-up”.

2. Outline and structure of this paper

The present article takes into account the first phase of a problem solving process. In particular, the procedure conceived by the authors is related to the analysis and abstraction stage of the method proposed by TRIZ, the theory of inventing problem solving [2]. Such a procedure allows the problem to be reformulated until its proper definition is achieved. Before introducing it, a brief excursus on problem reformulation has been treated in Section 3, citing the most important methods in literature, especially from TRIZ.

In the fourth section Bob-up, a procedure for the problem reformulation, is partially shown. Most of the philosophical reflections on the concept used to build this procedure are presented.

In Section 5, a deep analysis is dedicated to operational time (O.T.) and operational zone (O.Z.) identification. To support this step specific ontologies are given.

The last section presents an historical case, dealing with penicillin production, with the aim of showing how a procedure correctly working on O.T. and O.Z. identification can bring the solution.

3. TRIZ problem formulation and over

Many problem solving methods are dedicated to find and to shape the problem to be solved.

Already in first ‘70s the need to resolve problem with a congenial structure and definition for its solution was treated by Simon [3], that did the first definition of a well and ill-structured problem, underlining how, for an its systematic and repeatable resolution there is the need to convert an ill-structured problem in a well-structured problem [4-5].

Some methods try to lead the user to formulate the right problem in the more congenial mode comparing a system, or a problematic situation (as is) with its ideal state (to be) [6-7].

Other methods are more focused to work on causes of the problem. The real problem to solve is found exploiting modeling techniques based on cause-effect relations [8-10].

A different class of methods are dedicated to looking for an alternative problem formulation to solve, expressing it by alternative ways, introducing linguistics techniques, as the variation of verbs, nouns, adjectives, and parameters of the system [11-12].

Similarly there are methods that analyze the problem by more than one point of view, changing the observer for example, or trying to identify itself with the problem, or trying to analyze the problem by analogies [13-14].

Other methods focus their attention directly on the improvements of the system and on its functionalities improvement, creating and formulating the problem to be solved, by means of the combination of variable parameters of the system [15-16].

Also in TRIZ theory, the formulation of the problem is a topic of fundamental importance; in fact the quotation by John Dewey "a problem properly defined is virtually solved” [17] is often cited and universally shared. However it is still an open issue, and ARIZ (Algorithm for solving inventive problems) 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" appears. 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 the entire algorithm.

The versions belonging to the 1970s (ARIZ 71, ARIZ 75, ARIZ 77) had the problem formulation and analysis phase 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.

Since this version, the problem formulation stage remained unchanged in the following versions (82-A, B, C, D and 85-A) 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 judged too poor in rigors compared to the other steps. Also 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 disciples [18].

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[19-21], which help and try to guide the user to the first phase of problem approaching, consisting of information collection and problem formulation.

4. Bob-up overview

The proposed procedure is called Bob-up. Such a name was chosen to emphasize the role it has in emerging and surfacing the right problem, regardless of the complexity of the technical system considered.

Its task is to guide the user to select the critical element of the system. It tends to a clear reformulation of the starting problem in a more suitable way to solve it.

The validity of the method deals with systems both affected by negative effects and characterized by under-performance.

It consists of a series of successive reformulations (as shown in Figure 1) in order to identify the exact zone of the critical element on which an undesired effect acts (O.Z.) and on which intervention is required.

At the same time, the optimal functioning conditions of the system are identified; such conditions are the ones on which it is more convenient to introduce the solution (O.T.).

In this way the final formulation, derived by the procedure, takes into account exactly the place and the time in which the solution should work.

The procedure is applicable to all technical problems and even though it combines different methods and theories, it does not require specific knowledge about them.

The user is forced to think alternately at different detail levels, to change his point of view and focus his knowledge to understand what is happening in a specific O.Z. at a certain O.T..

In this way the method allows the search space of the physical interpretations to be limited only to the area involved by the possible solution.

With the aim to prevent time wastage and to contain resources required from the analysis of the entire operating system, the philosophy of the method is based on defining, at the beginning, the areas and the times that mostly require a physical explanation and only then suggestions to perform technical analysis are provided.

Bob-up is under testing by students at the last year of Faculty of Engineering, PhD students and industrial companies.

The method allows various users to produce very similar final formulations. This is achieved thanks to the subsequent questions that force the user to investigate the problem through gradually more defined areas and moments and with a strong awareness of what has to be expected from each step.

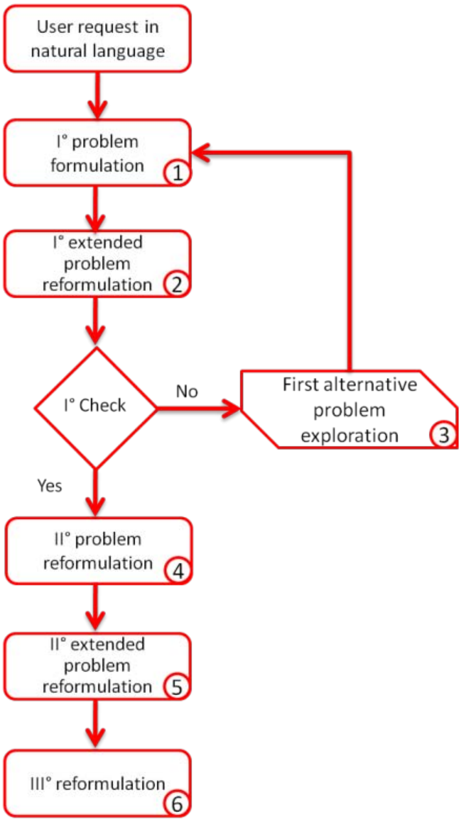

Figure 1: Bob-up schema.

4.1. The formalisms and the language

During the subsequent reformulations the user has to use different formalisms and to implement theoretical models forcing him to follow a systematic and repeatable path, converging to a unique idea/formulation of the problem.

Furthermore, steps are properly conceived to help the user to overcome problems derived by psychological inertia, responsible for the most frequent errors in a problem solving activity.

To do this, it is essential to combine an appropriate use of language with the graphic representation.

For this reason, the algorithm comprehends templates for a rigorous compilation of all the problem formulations, combined with lexical and semantic compilation rules. Only in this way the user can be sure that the influence of subjective interpretations or mental archetypes is greatly reduced. In the following sections a deep investigation about limits of language and the need for rules is introduced. For the same reason a sketch is introduced to accompany the textual description.

4.2. The sketch

As mentioned above, another key element that is used during all reformulations is the graphic representation.

Each step is supported by some sketching that helps the user to visualize and define in a more precise wayspaces, zones and elements, which the user is working on.

Again, during the exploration of the right detail level the sketch has the important task of guiding the identification of the exact area where the intervention is needed.

In fact, to eliminate the psychological inertia which limits the consideration of any system as homogeneous, graphic representation is one of the most effective tools that allows the identification of the differences that exist between different zones of a same element, or adjacent points within the same area. The sketch is merged with the language to overcome limits.

5. The O.T. and space

At the beginning of the analysis of a problem, it is quite impossible that people exactly define the same O.Z. and the same O.T.

Unfortunately, physical conditions and resources can radically change when space and time changes.

Starting from this initial premise, it is easy to imagine different interpretations of the systems and different directions to solve the same problem.

In order to make this phase convergent Altshuller, in ARIZ 85 C, defines the O.Z. and O.T. as the space and the time where the conflict indicated in the problem model appears.

Altshuller‘s philosophy in ARIZ 85C [22] is focused on finding a contradiction and only then looks at O.Z. and O.T. in order to separate and to find a good way to solve the problem by overcoming contradiction.

In this work, O.Z. and O.T. identification is anticipated as the at first part of problem assessment for defining good contradictions.

A brief example is introduced in order to show one of the typical failures occur during problem formulation process: thinking static what is dynamic.

Think about a dozen ice cubes which are melting into a steel pan on the stove.

What happens to the ice?

The most immediate answer should be that ice melts and until the water becomes completely liquid the temperature will be constant because the reaction is isothermic. Then a second image of the system, in a different operational time, will appear. When solid ice disappears the temperature of the water increases until a new phase, during which it will stabilize at about 100°C. During this time the water will start to transform into steam, until it evaporates entirely.

What is wrong in this description? Maybe nothing but maybe it is not the right way to describe the system if then we want to work on it.

In other words, we are not saying that the previous description is wrong, but simply that the dynamic interpretation is true only for certain O.Z. in a certain O.T., but it is false for other zones of the system.

A correct reformulation of the problem has to take into account this assumption. Let us see an alternative description.

Taking for example the initial time, when the system is formed by ice and hot pot, ice cubes will start to melt. The liquid water when in contact with the hot pot will evaporate immediately, and this phenomenon will increase more and more as we approach the outer surface of the ice cubes.

Similarly we could not define a period during which the temperature of the water remains constant. Depending on the zone and time, if we look closer, we will have variable conditions. The internal zones of the cube have a temperature similar to the freezer (-15°C).

A constant condition of approximately 0°C may be in a very thin surface above the part of the ice not in contact with the hot pan. And if we continue to look inside this thin surface of liquid, maybe a part of it, due to thermal exchanges with surrounding hot air, could not be exactly at 0°C.

As the system evolves, the zone where the temperature is constant will certainly be larger, but we could never talk about a constant temperature of the system as we did before.

The main hypothesis of this work consists of the assumption that to describe correctly a system it's necessary to understand all O.Z.s and O.T.s inside the system, and also space and time are not be considered independently.

The aim of the Bob-up procedure is to define a set of rules to systematically move to the right space-time coordinates of a given problem, avoiding psychological barriers.

The problem of framing the time and space of a product is not a new problem. Librarians for example, as well as the semantic web development community, have approached this topic in a very interesting way; librarians for cataloguing books and the web community with the aim of standardizing archives and databases affected by very different structures but full of similar concepts.

In the librarian field, we think about the O.T. for example when it is necessary to date a book before introducing it in the archive. O.T. is an entity by which it is possible then to activate a search and find it among millions of other books.

But, what is the O.T. for a book? Is it an instant or a period of time?

The answer to this question seems so banal, but it can hide some pitfalls. The more significant instant is the date on which the book was published. But as every system, the book is also a dynamic system and this date changes depending on the O.Z. we consider. In fact, depending on the language in which the book is translated, every edition has a different date. In addition, after selling all its copies, a book can be reissued with a new date and most archives also take into account the following editions.

If we reformulate the initial question, asking when a book starts to live, probably not all converge on the date of the first edition, but new concepts of time will appear:

- the date on which the writer had the inspiration;
- the date when the author began to write;
- the period of time in which the book is written;
- the date when it was finished;
- the date when for the first time it was possible to read it (if blocked by the censors).

A further investigation shows that the concept of O.T. is not limited to the previous identified operative times. In fact, the book's O.T. does not necessarily belong to its author, but may belong to the book itself. It could be the date on which the material copy of the book is created! But it could also be the time of the content of the book. Again, if we look closer into the book we can meet up with a lot of concepts, which are just as interesting.

In support of this, the book can tell a story that can evolve in a single day rather than in many centuries. Also the story can be contextualized in a recent historical period or in a far-off time.

The book cataloguing case is not so different from what happens to a problem solver when he faces a technical problem of which it is necessary to analyze the conflicts.

To take into account such a variability of the O.T. concept, it is necessary to define an accurate ontology that helps us to define uniquely and precisely temporal concepts.

A work, completed by an interdisciplinary team to create the International Committee for Documentation of the International Council of Museums (CIDOC) Conceptual Reference Model (CRM), is proposed. The goal of this team is to provide a high-level ontology to enable information integration for cultural heritage data and their correlation with library and archive information. The CIDOC CRM analyzes the common conceptualizations behind data and metadata structures to support data transformation, mediation, and merging [23].

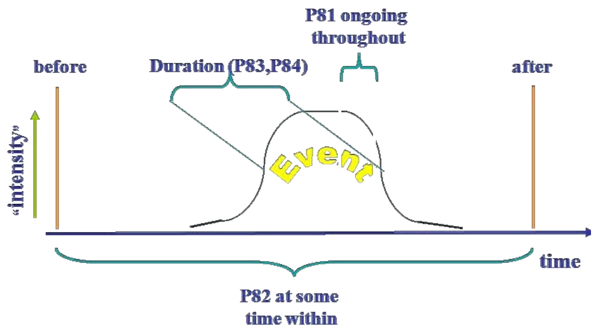

Figure 2: CIDOC CRM and Time.

Time is one of the topics of the CIDOC works (see Figure 2). Different groups worked on different concept of time: period, duration, instant. From all CIDOC works, we propose the classification shown in Figure 3. Here ontology is presented by identifying the entity of the time by means of two different classifications: the period and the state condition.

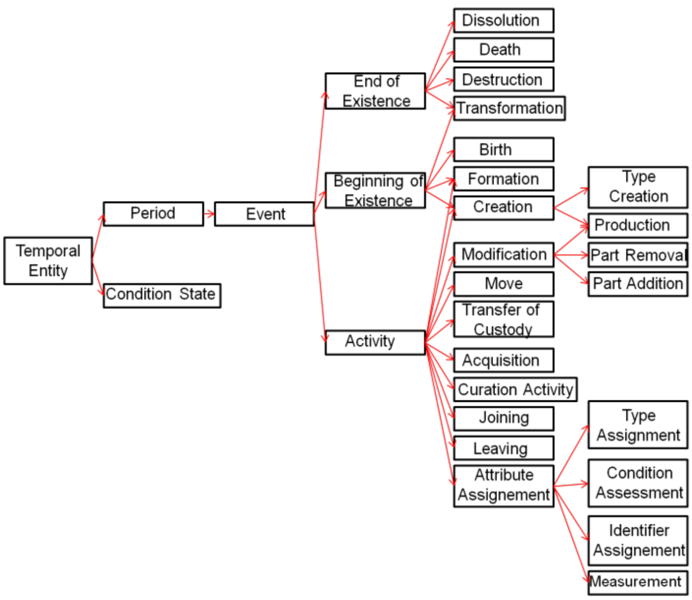

Figure 3: Time ontology from CIDOC-CRM.

Every period can be decomposed into events that can be described by means of “the beginning of a phenomenon”, “the end of a phenomenon” or linked to a “specific activity”. Consequently every entity can be connected with other elements that can help the definition of every period without ambiguity.

Ontology can help to define entities related to time in order to define exactly what we have in mind. Now the problem is how to communicate this idea.

Language can be a solution, but not without some harmful consequences. From a philosophical point of view the language creates nor an objective time, neither any single instants, but it produces a specific temporal semiosis.

Gullaume, Moietta [24] calls the “operational time” the time that the mind employs to make an image of the time. Our task is to create an idea of the time that can take into account whatever time-image is not suitable to describe the time process needed to build that image. In order to define a right model of time we have to think of the time as finished and consider the time built as a time existing inside the time needed to be built.

For Aristotle the “operational time” is the measure through “before” and “after”, and therefore the space is tightly necessary to define the time.

From this Aristotelian thought, the unique way to correctly represent the time of our problem is to define first an O.Z. This is done in Bob-up at the beginning of the problem analysis, connecting O.Z. to the element affected by the harmful effect.

Hence, it is possible to develop a first O.T. formulation and starting from here it is possible to produce a wider explanation of the phenomena that leads the user to understand if the starting O.Z. is correctly identified at the right level of detail.

Having redefined the O.Z., it is consequently necessary to adjust again the O.T. for that zone.

5.1. However, time is ever dependent on the space.

For that reason we also suggest ontology of the space, as shown in Figure 4. To correctly define the space a huge number of entities could be needed.

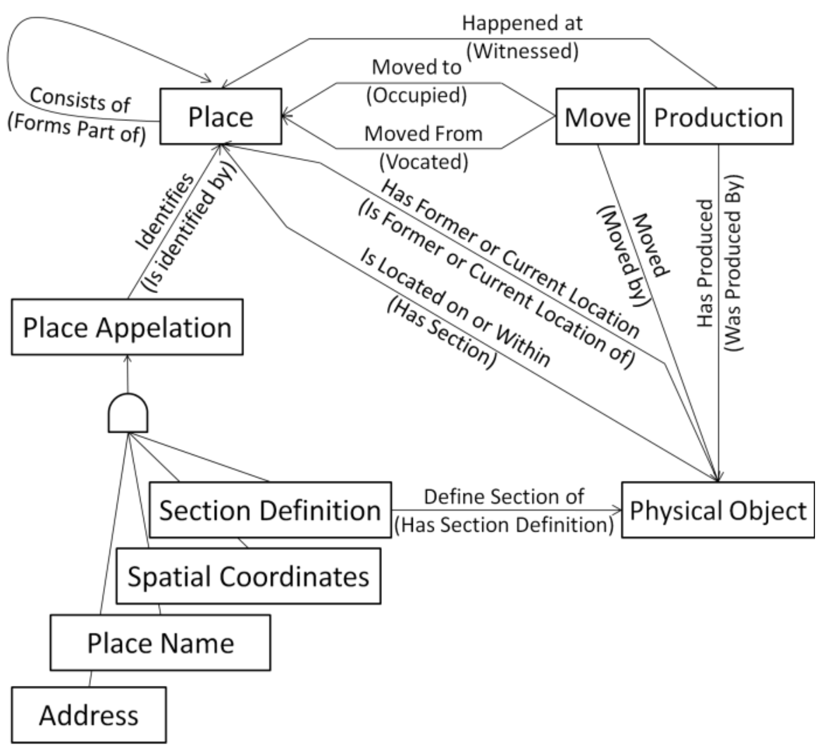

Figure 4: Space ontology.

However a deeper explanation of the concept of the space goes beyond the purpose of this article.

5.2. O.T. by natural and technical system conflict

In the Bob-up procedure we do not force the user to identify O.Z. and O.T. at the first shoot, but by means of a series of steps and problem reformulations. We do not only use language but we introduce templates and forms with the aim to limit ambiguity. Finally, sketch is integrated with textual description in order to overcome language limits.

The last problem to be solved is how to define the right instant of O.T. once the O.Z. is fixed. Having the right space-time coordinates means it will be easier to describe physical dynamics and phenomena of our problem if we have enough knowledge about it.

The idea to fix the O.T. is avoiding the use of the language by introducing a new specific graphical tool representation: a Cartesian diagram showing the conflict between a natural and a technical system.

Now the O.T. is found by looking for the trigger of the harmful effect.

For the right identification of this temporal instant in the fixed O.Z., the system is analyzed by a physical point of view. Subsequently it is represented only by a contraposition by two antagonist systems: the technical and the natural one.

The technical system tries to perform the useful function as we want, in the desired way. It is the system that we introduce to do what we want against nature that cannot do the same alone.

The natural system is the antagonist to the technical system. It is the spontaneous behaviour of nature that opposes our intervention. It counteracts the normal operation of the technical system, avoiding the correct undertaking of the main useful function, or provoking harmful effects that compromise the performances of the system.

To formalize the technical and natural systems, we represent them by means of a Cartesian graph.

On the X axis, time units are compared. On the Y axis it is possible to choose from force, pressure, energy, power, fluency, etc. There is only one rule: natural and technical system lines must cross or must be convergent as an asymptote.

It is not important how accurate the diagram is, or what unit we took for the Y axis. The key is the methodological path followed to find the cross diagram among all different potential representations. Filling this diagram wants to be a stratagem conceived with the aim of scanning specific zones and transients looking for where the crossing point really appears.

When the cross point appears, a new definition of O.Z. appears. O.T. is the instant when a new process, a new phenomenon, a new configuration modifies the status of the system. From this physical point, well collocated in time and space, starts the description of events inside the problem we have to face to. The time in the diagram is the time the solution has to start to work. The final reformulation has to take into account this information.

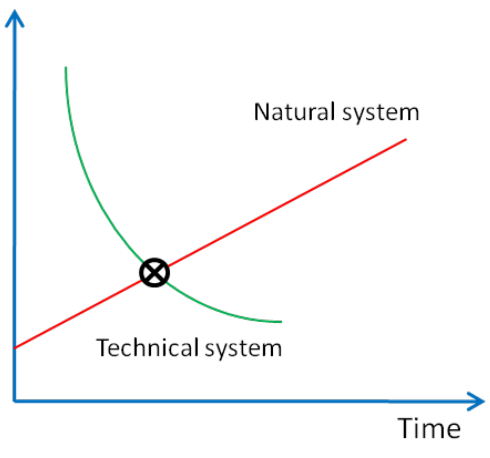

Figure 5: Cartesian graph for O.T. identification.

6. Case study

In order to better explain how the procedure for the reformulation of a problem works, a case study that focuses on the identification of the O.T. into its O.Z. will be presented.

The case study is related to the invention of penicillin and its production on an industrial scale.

In 1929 Alexander Fleming discovered the property of penicillin to kill bacteria.

The mould was a much better killer for some kinds of bacteria than all previously tested chemicals. Fleming discovered that penicillin kept in solution for two weeks lost its properties, but if dried it could be kept for a long time.

Fleming derived dry penicillin by heating the solution very slowly to evaporate water. He wanted to increase the rate of the process, but high temperature killed the mould. The slow rate of evaporation was too slow to manufacture a new medicine. Fleming tried to solve the problem, but he was unsuccessful.

Fleming's system has the ability to remove the water through evaporation from the container where the water is contained together with the mould. In this way it was possible to obtain dry penicillin.

In order to have a big evaporation rate, the physics principle chosen by Fleming is the need to heat the water, until evaporation temperature. This temperature goes from environment temperature to boiling temperature, that is 100°C at sea-level pressure. A temperature near to 100°C causes the death of penicillin in little time, Fleming wanted to heat the water at temperatures near to 100°C, to reduce evaporation time (Figure 6 shows Fleming's system).

The harmful effect that is felt from Fleming is the penicillin's death.

It is now possible to define the O.Z. of the harmful effect, starting from the element that suffers from the negative effect. The damaged element is the penicillin.

Investigating how the physics of the harmful effect develops, it emerges that the penicillin changes its resistance depending on the temperature. In particular, the higher the temperature, the shorter the time of penicillin resistance.

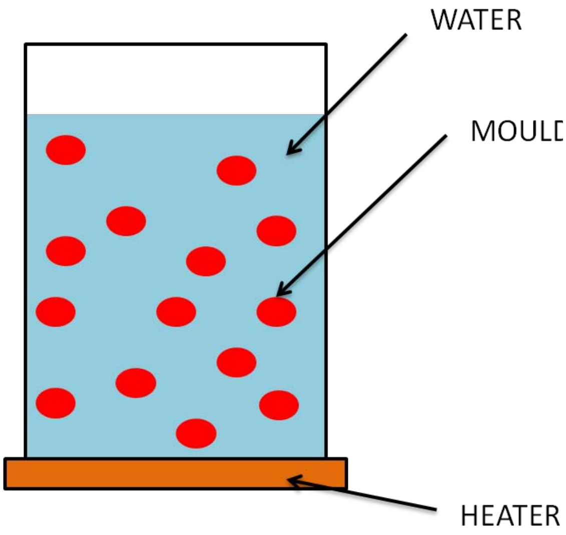

Figure 6: Fleming's container.

To find the specific moment at which the harmful effect appears, it is necessary to identify the technical system and the natural system.

The technical system, represented by the green curve in Figure 7, describes how the system works. The curve increases until water evaporation (horizontal line). The furnished energy is the area under this curve.

Instead, the red line represents the natural system, that is, the behavior of the penicillin subjected to heating. It represents the resistance in time of the penicillin, and it is easy to understand how the penicillin resistance decreases as the temperature increases.

The intersection of the two lines sets the trigger of the harmful element off, that is, when the furnished heat overcomes the maximum that the penicillin can receive; the harmful effect starts and the penicillin dies.

If we consider the heat from the heater, and the thermal inertia of the water, the latent heat, the specific heat of the water and penicillin, it is possible to assert that the crossing between the natural system line and the technical system line, is after few minutes at a precise temperature T* .

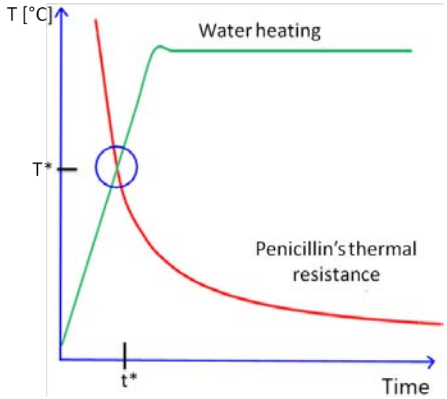

Figure 7: O.T. for harmful effect.

But is the trigger of the harmful effect in every zone of the system the same?

The answer is certainly no, because there are no homogeneous systems. As shown in Figure 8, the temperature of the water, into the penicillin container, is not constant.

So the O.Z. and the O.T. have to be redefined. In particular we decided to analyze three O.Z.s indicated by three rectangles (see Figure 8).

In zone 1, zone 2 and zone 3 there are important temperature differences that involve different O.T.s, as shown in Figure 9.

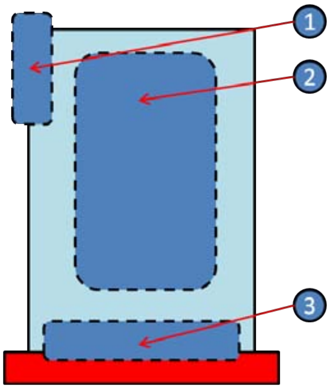

Figure 8: Thermo-graphic representation of Fleming's process.

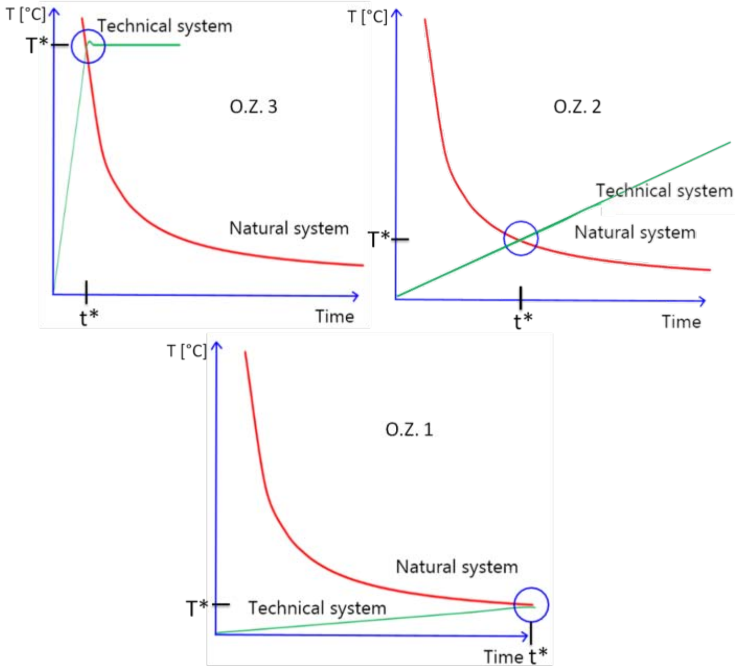

Figure 9: Different O.T. for different O.Z.

Figure 9 shows that different O.T.s are involved, depending on the O.Z. considered. This means that depending on the considered O.Z., different solutions can be inserted in different zones and in different times.

Let us take into account the worst problem condition (O.Z. 3).

Increasing the detail level of the sketch in a new O.Z. it is possible to see hot water particles heating penicillin. Not all the water, but water at high temperatures in direct contact with a single penicillin cell (Figure 10).

The high temperature of these water particles is necessary to cause a fast evaporation.

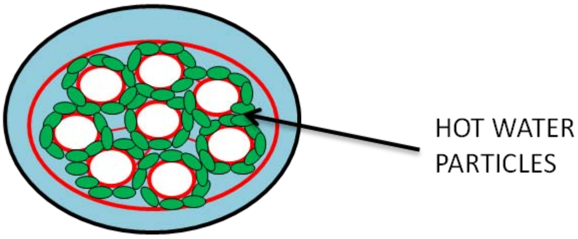

Figure 10: Penicillin at micro-level with hot water particles.

So the final formulation of this problem according to final O.Z. and O.T. is: the water particles in contact with penicillin's cells need to have a high temperature in order to fast evaporate; but in this way when T goes up to T* they kill the mould.

An identikit solution has to introduce an X element causing the evaporation of water without overcoming T* (according to the variability of T* in any point and at any time of the system).

Physics can offer some solutions. Just looking at the diagram in Figure 11, a design parameter is suggested, decreasing the local pressure.

The real case was solved by Ernst B. Chain and Howard W. Florey in 1939, passing from the solid phase (freezing the water) to the gas phase without passing through an intermediate liquid phase. Sublimation can be controlled by temperatures and pressures below a substance's triple point in its phase diagram.

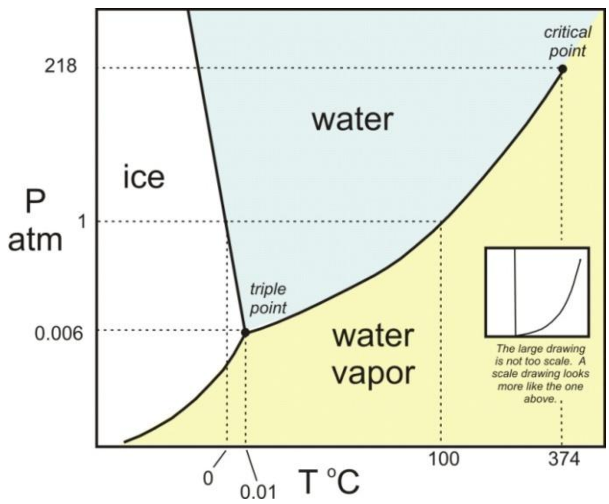

Figure 11: Water phase diagram.

7. Validation

A first validation of the method is still in progress. It involves Master Degree students in Mechanical Engineering and Management, PhD students and companies.

Test consists of a set of exercises, a mix between known case studies taken from the history of science and technology and current works from consulting activity with companies.

Following the Bob-up procedure, users have to fill in the blanks of the software and fix the element affected by undesired effect in its O.Z. and O.T.; it is described both by sketch and by a textual description.

Results are compared with a reference model of the solution created by a reverse process using known solutions of each problem to deduce the best element at the right O.Z. and O.T.

Final score is calculated taking into account a list of criteria as follows:

- the element is correct in the right O.Z. and O.T;
- the element is correct in the right O.Z. but O.T. doesn't match with any solution time;
- the element is correct but O.Z. shows the problem at a detail level where it is potentially difficult to find some solution;
- the element isn't correct.

Final validation isn't not available yet because the number of samples is not sufficient to provide a reliable statistic; Nevertheless current results have already shown very encouraging results.

In fact:

- the choice of the element is in all cases correct.
- O.Z.s are correctly identified in almost all cases. Typical mistakes are to visualise the element by a 2D sketch and then forgetting part of the O.Z. laying in the third direction of the space. Another typical mistake is to conduct the analysis in an hasty manner during the micro level sketch representation. When it happened O.Z. was bigger than target O.Z., so demonstrating that accuracy of this step strongly influences the correct O.Z.s representation.
- A previous knowledge about the problem can influence the filling time but not the final result. No difference was found between users from different cultural background (PhD, student or companies).
- In the final version of the software, ultimate textual reformulations really converge, while sketches not yet.
- The choice of the physical quantity to be put into the Cartesian graph for O.T. identification, has a minimum influence on the final O.T. identification. There are large discrepancies on results only when the physical interpretation of the system is totally wrong.

- O.T. identification has a lower success rate than element and O.Z.. However this rate is greater than 75% of cases.

The overall results will be shown during the conference.

8. Conclusions

Once again it was shown that without an appropriate analysis of the problematic technical system, at the beginning of every problem solving activity, it is very difficult to find the best solution for that problem.

A good reformulation of the initial problem can sensibly help problem solvers to find the right solution or to correctly set up a TRIZ activity.

This work presents a part of a set of rules, called Bob-up, conceived by the authors to better define the right reformulation of the initial problem. Most theoretical considerations about the concept used to build this procedure are presented.

Research group of University of Bergamo has been working on software that helps users to correctly follow all steps of the procedure.

An exemplary case study is presented about the invention of penicillin industrialization.

A first validation of the method is still in progress but current results are very encouraging.

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Reference

[1] Stevens G., Burley J., 1997, “3,000 Raw Ideas = 1 Commercial Success!”, Research-Technology Management., 1997

[2] Altshuller G.S., 1984, Creativity as an exact science: the theory of the solution of inventive problems, CRC Press, ISBN 9780677212302

[3] Simon H.A., 1973, “The structure of ill-structured problems”, Artificial Intelligence. Volume 4, Issues 3-4, 181-201.

[4] Buck J.R., 1978, “Manual optimization of ill-structured problems”, International Journal of Man-Machine Studies vol. 10, no. 2, pp. 95-111

[5] Simon H.A., Newell A.,1971, “Human problem solving: The state of the theory in 1970”, American Psychologist, Volume 26, Issue 2, Pages 145-159.

[6] Manktelow J., 2005, Mind Tools, Swidon, Mind Tools Ltd, ISBN 9780954558611

[7] Shetty D., 2002, Design for product success, Dearborn, Mich, Society of Manufacturing Engineers, ISBN 9780872635272

[8] Bjørn A., Fagerhaug T., 2006, Root cause analysis: simplified tools and techniques, Milwaukee, American Society for Quality, ISBN 9780873896924

[9] Ishikawa K., 1985, What is total quality control? The Japanese way, Prentice-Hall, Englewood Cliffs, ISBN 978-0-139-52433-2

[10] Ohno, T., foreword by Norman Bodek ,1988, Toyota production system: beyond large-scale production, Cambridge, Mass., Productivity Press. ISBN 0915299143.

[11] Fogler H.S., LeBlanc S.E., 1995,. Strategies for Creative Problem Solving. Prentice Hall PTR, ISBN 9780131793187

[12] Eberle B., 1996, Scamper: Games for Imagination Development, Waco, Prufrock Press, SBN-1-882664-24-8

[13] Morgan M., 1993, Creating workforce innovation: turning individual creativity into organizational innovation, Chatswood, N.S.W.: Business & Professional Publishing, ISBN 187-5-68002-0

[14] Gordon W.J.J., 1961, Synectics: The development of creative capacity, Oxford, England: Harper, xi, 180 pp.
[15] Zwicky F., 1948, The Morphological Method of Analysis and Construction, Courant, Anniversary Volume, New York: Intersciences Publish.
[16] Crawford R.P., 1979, Direct Creativity, with Attribute Listing, Fraser Pub. Co., ISBN 978-0-870-34009-3
[17] Dewey J., 1910, How We Think, D.C. Heath and Co., Boston-New York
[18] Zlotin, B., Zusman, A. ,1999,. “ARIZ on the move”, Triz Journal Volume of March
[19] Zlotin B., Bushuev D., Haimov E., Malkin S, Zusman A., Tikhonov A., Pevnev V., 1996-12-03, Automated Problem Formulator And Solver, US Patent 5,581,663
[20] Zhang G., 2008-11-18 System for problem statement reformulation US Patent 7,454,391
[21] Devoino I., Koshevoy O., 2000-05-02, Computer based system for imaging and analyzing an engineering object system and indicating values of specific design changes, US Patent 6,056,428
[22] Altshuller G.S., 1969, Algorithm of Invention, 1st edition, Moscow, Moscow Worker
[23] Doerr M., 2010, “The CIDOC conceptual reference module: an ontological approach to semantic interoperability of metadata”, AI magazine, vol 24, no 3,
[24] Moietta E., 2002 “il tempo operativo” (in eng. “the operative time”), Bateson Circle Seminar, Roma, 1-2 June.