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APPROACH TO AN INTEGRATION OF TRIZ AND HEURISTIC METHODS FOR THE DEVELOPMENT OF INDUSTRIAL PRODUCTS

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1. Introduction

Any industrial product can be view as a practical constructive solution for the principle chosen to perform a given function. The principles, as to say the conceptual abstraction or the concept of the constructive solution, can be known or new [1].
The known solutions come usually from the historical heritage and from the actual industrial practice. The authors developed a design method (see [2] and [3]) that integrates the historical heritage (a collection of catalogues and data-base of historical solutions) as a tool that could help the designer in the abstraction process.
On the other hand, the new solutions could be developed by means of heuristic methods, TRIZ [4], and the nature observation.
In our paper, a further step toward the integration between heuristic methods and TRIZ in the design process will be deeply illustrated (Figure 1 shows a general schema).

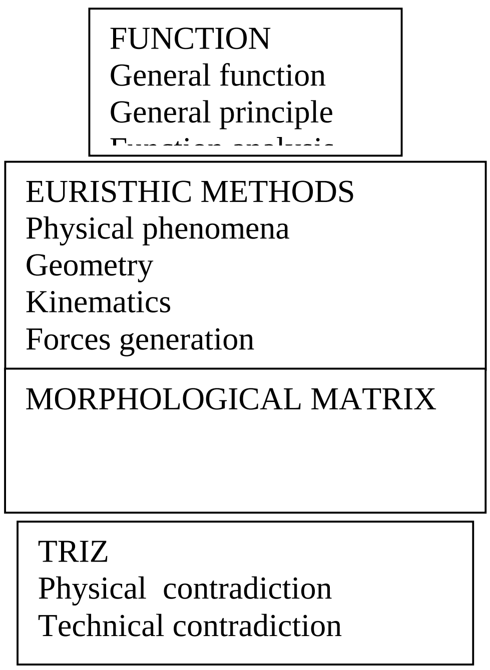


Figure 1. General schema of the integration between heuristic methods and TRIZ.

2. Proposed design method

In this section, the four fundamentals steps of our method will be briefly summarized.

After the definition of the general function, it is necessary to choose the general principle (e.g. mechanical, electrical, biological, and so on). After this choice, it is necessary to analyze the general function, in order to highlight the sub-functions.

The second step consists in the individuation of the principles for each sub-function on the basis of physical (or, more in general, natural) phenomenon, geometrical (forms of surfaces) and kinematics (motions of surfaces) interactions and resulting forces, and so on.

The third step consists in the realization of the morphological matrix: the rows are the sub-functions and the columns are the principles that could perform each sub-function.

By means of *Design for X* criterions, it is finally possible to choose the "best" principle (or principles) for each sub-function (as to say for each row): trying to achieve a congruent synthesis of the resulting "sub-principles" the designer could develop new principle (or principles) for the general function. These general principles must be, of course, evaluated and, if necessary, chosen also on the basis of *DfX* criteria.

The fourth and last step relies on the TRIZ method that could help to individuate physical and/or technical contradiction: the corresponding inventive principles could then improve the general principles previously found.

3. A first example

As example, the following problem will be developed:

0. Function: apply a 90° rotation to a force line of action, reducing, as much as possible, the component normal to the line of action of the displacements of the points of application.
1. General principle: mechanical, which embodiment could be a square lever (Figure 2).

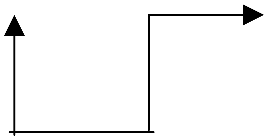


Figure 2. General principle (mechanical) for the given function.

2. Sub-functions
   - F1 = application of input force
   - F2 = application of output force
   - F3 = linkage to the frame
   - F4 = connection among previous functions (F1, F2, F3)
3. Sub-principles individuation
   - 3.1. Morphological Matrix: Table 1
   - 3.2. Choice and synthesis: The principle and the constructive solution for each sub-function should be chosen on the basis of *DfX* criteria. The principle/constructive solutions for the complete product have to be a congruent synthesis of the principles/constructive solutions among all the sub-functions. Figure 3 shows the chosen solution that satisfies all these criterions.

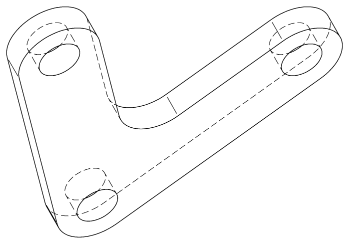
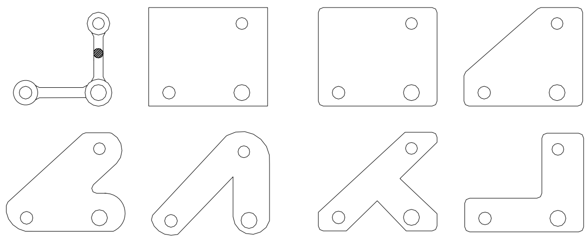


Figure 3. Square lever solution

4. *TRIZ* application
The found technical contradiction could be summarized as follows: as the force grows, the square lever dimensions have to be increased: in particular the arm length and consequently the force application point displacement increase.
According to *TRIZ*, the involved inventive principles are: 7, 17, 4, and 35. Principle 35 named “Parameter changes” and, particularly, “Change an object’s physical state” is the more promising. In fact, the physical contradiction could also be the formulated as follows: there is the square lever but (because of its space occupation) it would be also useful that the lever would not be there (its arms should have zero length).
A solution could then be another constructive principle: a curved pipe that transmits forces by means of a liquid compression (Figure 4).

Table 1. Morphological matrix.

Sub-functions	Principles
F1	Pin symmetric, pin asymmetric, hole symmetric, hole asymmetric
F2	Pin symmetric, pin asymmetric, hole symmetric, hole asymmetric
F3	Pin symmetric, pin asymmetric, hole symmetric, hole asymmetric
F4	

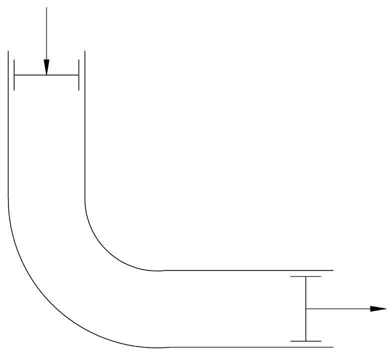


Figure 4. New solution by change of physical state, by means of TRIZ contradictions.

4. A second example

If we consider a nutcracker, it would be possible to choose the principle among a wide set: Geophysical, Biological, Mechanical, Hydraulic, Pneumatic, Electromagnetic, Nuclear, Chemical…
Analyzing in detail each of these categories, it is possible to expand this list: for example the hydraulic and/or pneumatic principles can be further subdivided into principles that apply an external or an internal pressure to the nut. Likewise, also the mechanical principle family

could be subdivided in sub-families on the basis of the kinematics of the two approaching surfaces that will break the nut (see Figure 5):

- surfaces with translational motion: all the point of a surface have the same speed vector but with opposite direction on the two surfaces;
- surfaces execute a rotational motion: it exists at least one point that does not move (this point could not exist physically, but it has to exist if the theoretical unlimited surfaces are considered).

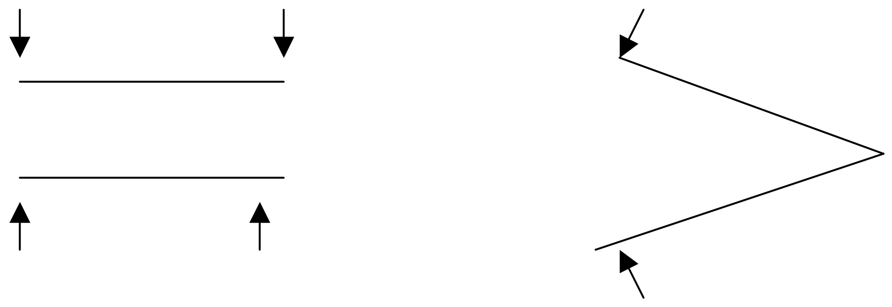


Figure 5. Two mechanical principle sub-families for a nutcracker.

For sake of brevity, we will assume that the mechanical principle with surfaces in rotational motion has been preferred. Actually, during the design process, this conclusion would be the result of a product lifecycle analysis relying on *DfX* methods. Since the proper principle has been singled out, it is possible to draw a simple sketch that will be the basis for the analysis of the general function (see Figure 6).

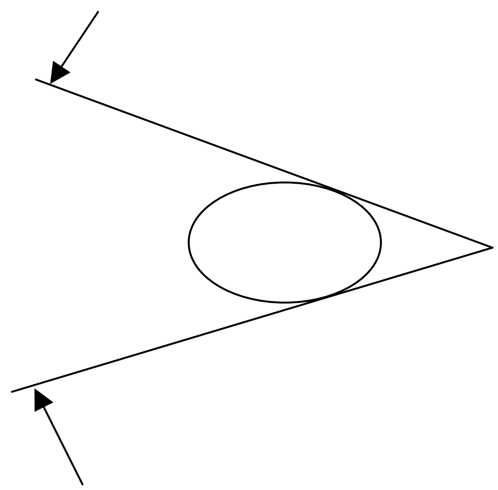


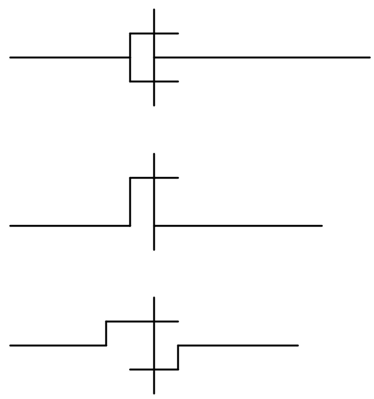
Figure 6. Product functional sketch.

The subsequent step for the development of the product consists in the subdivision of the general function in the sub-functions. A functional analysis of the nutcracker based on the chosen mechanical principle shows the existence of three main sub-functions:

A. block the nut;
B. apply the force;
C. realize arms relative rotations.

Table 2 shows the corresponding morphological matrix.

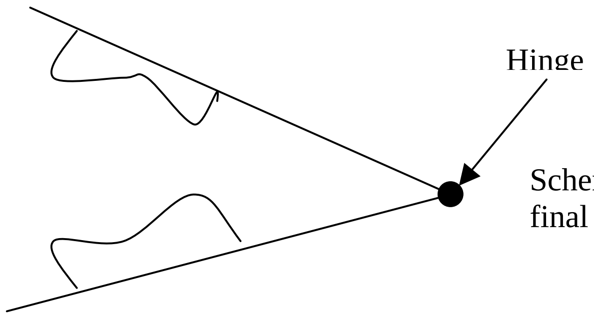
Table 2 Morphological matrix

A	**block the nut**	**Force principle: the nut is blocked by means of forces acting directly on it.** **Form principle: the nut is blocked thanks to the proper shape of a zone of each arm.** **These principles can be applied on the upper arm, or on the lower, or on both.**
B	**apply the force**	**Direct: the force is applied directly on the arms. The force is however amplified thanks to the lever mechanism.** **With interposed mechanism: the force is applied on an additional mechanism that will further amplify the applied force. These additional mechanism could be:** **cam** **crank** **screw** **…..**
C	**realize arms relative rotation**	 **A wide variety of solutions is available.** **Only three sample schematic sketches are drawn.**

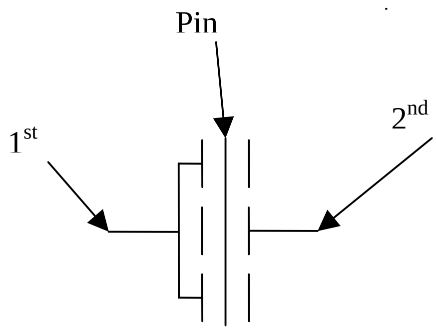
The following step consists in the choice of an adequate principle for each function, followed by a synthesis of the chosen principles. At the end of these procedures, a general schema of the nutcracker can be drawn. In the development of our product the following solutions have been adopted:

A. block the nut: form principles on both arms;
B. apply the force: direct
C. realize the relative motions of the arms: fork end at an arm and hinge with pin

Figure 7 shows the resulting schema.



Schematic representation of the final arm zone properly shaped to



Schematic representation of a simple constructive solution for the hinge connecting the two arms.

Figure 7. Final schema of the product.

The pin of the hinge is an element that could have negative effect: it requires a more complex arm structure and increases the nutcracker dimensions and weight.
On the other side, the pin is necessary to allow the relative rotations of the arms.
By means of the TRIZ principles, it is possible to solve this contradiction. According to TRIZ terminology, it is possible to recognize a physical contradiction: there must be a pin and there must not be a pin. The TRIZ ways to overcome the physical contradictions are the following:

– separation in space: no specific ideas;
– separation in time: no specific ideas;
– separation in structure: pin integral with the first arm (see Figure 8);

separation in physic state: pin substituted by elastic elements.

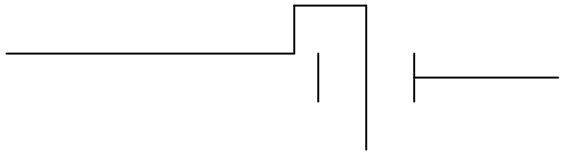


Figure 8. Separation in structure.

5. Conclusions

Heuristic methods, morphological matrix and TRIZ are very useful tools and methods to develop new principles and constructive solutions, or to apply already known solution and principles outside the scientific, technological, and technical environment. The authors believe that an integration of these methods could be a very useful development in their usage within the design methods.

This paper presents some of the authors' first steps in this direction and they hope that it would be a basis for further discussion and research in this area.

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