Envisioning the future of your technical system through analogies and adaptation

The definition of a finite set of possible alternative about the future development of technical systems is a critical issue in every company that aims at proposing innovative solutions to their customers. By means of this anticipatory analysis, the companies can plan, with appropriate resources and time, the development of their products, processes or services so as to both match the specific demands emerging in various contexts and consistently with the latest advancements of science and technology.

Consistently with this framework, the FORMAT methodology is currently articulated into several tasks that contribute to build a better understanding of the future for a specific technical system under investigation. In detail, for those activities specifically oriented towards the identification of the future characteristics of technical systems and the contexts they operate in, two opposite but complementary approaches have been included in the structure of the FORMAT methodology: a qualitative and a quantitative one. Figure 1 shows the two approaches as a single pillar for the forecasting activity. It is also subdivided into three different viewpoints that, after separate analyses, have to be reconciled into a unique and integrated forecast.

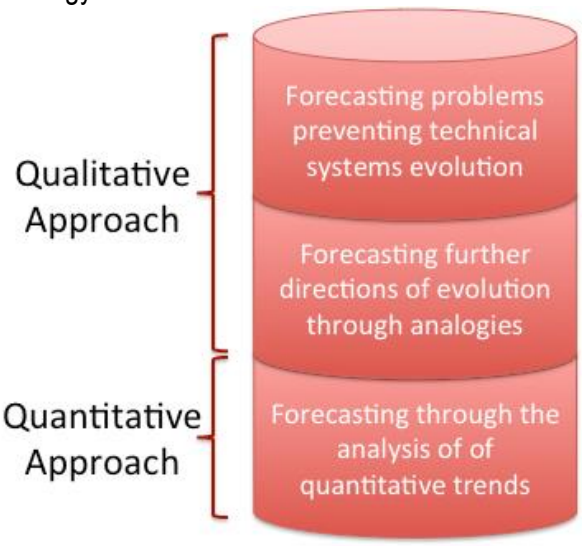

Figure 1: The complementary activities of the FORMAT methodology that contribute to the definition of a unique and comprehensive forecast.

As it comes out of Figure 1, the qualitative approach can be tackled from two different perspectives: a problem-based and a solution-based logic. In details, this white paper aims at presenting the approach for envisioning new directions of development for technical systems, following a solution-based approach (central section of the pillar of Figure 1).

The FORMAT methodological approach for envisioning new solutions

The FORMAT approach for defining opportunities for the future development of the technical system under investigation can be visualized as a three-steps track, as it is depicted in Figure 2.

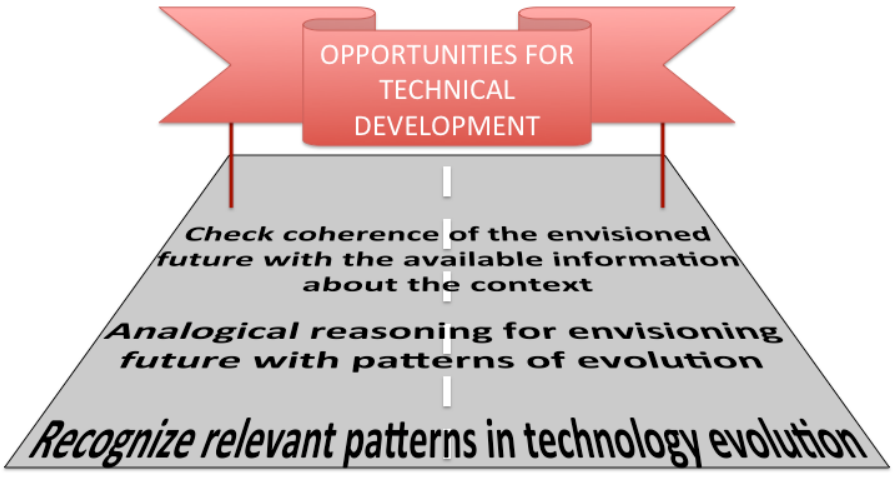

Figure 2 The road separating the analysts/forecasters from the structured definition of evolutionary scenarios for the technology under investigation. The three steps embedded in the overall FORMAT methodology should be faced one after the other, starting from the lowest part of the road, moving towards the red banner.

It is worth saying that the next part of this white paper presents examples from two different domains. The first step of the approach (which is fully related to the evolutionary analysis of the state of the art) is presented with reference to the polymer forming technologies, especially considering the evolution of the vacuum forming technology, being it the subject of the case study on which the first release of the FORMAT methodology has been applied. As for Figure 2, the next two steps of the approach for envisioning new solutions will be presented with reference to a different domain. The application of the approach in the field of automotive industry will allow the remaining part of the approach to be described with meaningful and replicable examples and without infringing the confidentiality issues behind the case study on vacuum forming technologies.

The first step of the envisioning approach deals with the **recognition of already relevant evolutionary patterns** in the technical domain under investigation. In other words the analysts are required to study the history of the technology at hand. This initial analytical step aims at understanding

- what are the major changes that characterize the evolution of the technology; together with
- the needs that have driven this evolution from the past to the current time.

With reference to the Vacuum Forming technology, one of the forming alternatives considered during the application of the first release of the FORMAT methodology, it is possible to identify some relevant and significant steps in the evolution of the technology. Figure 3 shows the complete evolutionary pattern for such a forming technology.

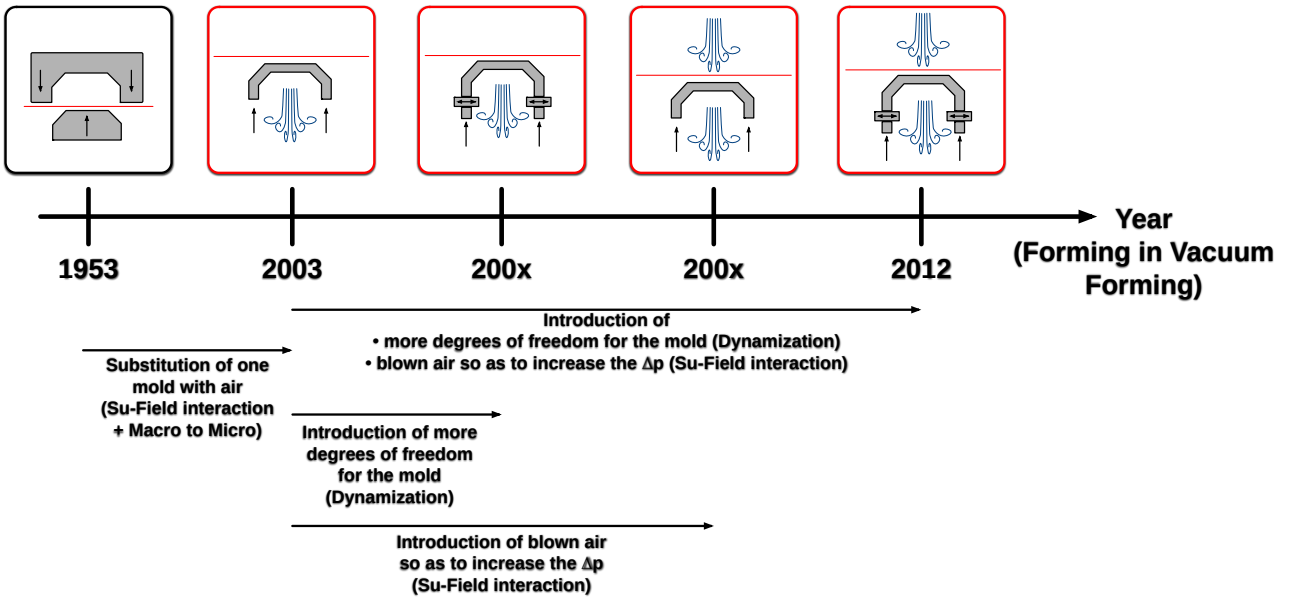

Figure 3: the evolutionary path for the vacuum forming technology. The timeline and the related images show the elementary stages of this technological evolution. The arrows (lower part of the figure) clarify the specific evolutionary trend according to the TRIZ body of knowledge.

From left to right, in Figure 3, it is possible to recognize the evolutionary steps that have characterized the vacuum forming technology along the years. Using a lineage metaphor, it is possible to recognize the metal stamping (black box of Figure 3) as the eldest ancestor of the vacuum forming. Two reciprocating molds move towards each other (more often one of the two is kept still) in order to confer the (sheet) metal an appropriate shape. With less stiff materials (e.g. polymers) it is possible to substitute one of the two molds, whose manufacturing is highly expensive, with air that gets sucked from small holes in the surface of the remaining mold. In this way, the sheet to be formed can adhere to the mold by getting pulled on its surface. This configuration corresponds to the most elementary behavior of the vacuum forming technology (first red box from left, Figure 3). Several other advancements have been introduced in order to reduce the time for forming plastic sheet, the quality of the shape and to ease the removal of the mold from the formed plastic product. Such changes deal with

- the introduction of molds having a higher number of degrees of freedom (with reference to the main direction of movement, some of its parts are allowed to move orthogonally - central box in Figure 3)

- the addition of blown air from top, that enforces the action of sucked air, in order to achieve higher precision levels and speed up the process (third red box from left, Figure 3).

The latest and more advanced available vacuum forming technology integrates all these changes and concludes the state of the art analysis for the technology at hand (last red box from left, Figure 3).
Hence, this first methodological step has the purpose of supporting the analysts/forecasters in identifying relevant evolutionary patterns already emerged in the technological domain under investigation. In other words, before the unconstrained application of analogies by means of a large set of evolutionary trends available from literature (e.g.: technical, economic, social trends); the FORMAT approach for envisioning new solutions aims at reducing the efforts for generating new ideas by identifying a small subset of trends, which collects what should be considered relevant in the field in which the study is carried out. [1]

Moving ahead on the road tracked in Figure 2, it is necessary to start applying analogical reasoning and to envision solution concepts that have to be adapted for the technology at hand. In order to define such opportunities of development, it is possible to draw inspiration from the stimuli provided by the trends already identified from literature. As briefly mentioned above, the trends don't have to be necessarily linked to the technical domain; on the contrary, wider the variety of trend domains the forecasters include in their approach, more comprehensive and reliable the results of the forecast are expected to be. They are usually defined at a general (even abstract) degree of description, so that it is possible to recognize similarities across different domains. The analysts are, therefore, asked to check if it is possible to **build analogies between the abstract level of the trends and the technology under investigation**, together, with the necessary adaptation (which is more and more necessary for analogies with non technical fields, since the related solutions can easily go beyond the technological domain). Figure 4 presents a graphical example of the reasoning process to be followed for generating opportunities of technical development in the future through the application of the TRIZ trend of Dynamization [2]. Other examples of TRIZ trends and laws of technical systems evolution are available in [3]. Trends from other domains and dealing with non-technical issues are also available, e.g., in [4].

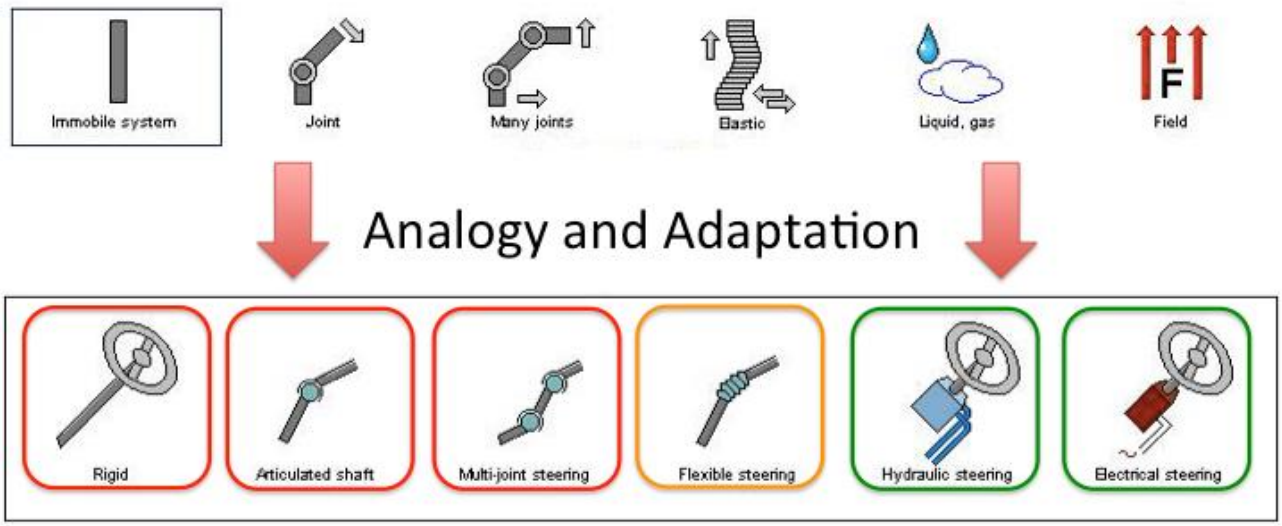

Figure 4: Example of application of the logic underlying the definition of future opportunities of development for the system under investigation, with the TRIZ trend of dynamization (pictures retrieved and adapted from http://www.triz.co.kr). Analogies between the trend (top of the figure) and the technical system (bottom of the figure) suggest the analysts to look if some of the envisioned solutions have already emerged in the market (red rounded box), if some others are emerging (yellow rounded box) or if some of them can be expected in the future (green rounded boxes).

As for Figure 4, the Dynamization trend has been adapted to the steering wheel for cars. The shaft connecting the steering wheel to the front axis of the steering system is now evolving towards more and more sophisticated solutions. The early monolithic shaft has now evolved towards a set of rigid segments connected through joints that make it more adaptable to complicated geometries so as to optimize the room required and the layout of other car components (red rounded boxes). Flexible steering shafts (yellow rounded box) are

progressively introduced in the automotive domain, even if this kind of solution is far from being considered a standard. Nevertheless, the highest potential of this approach stands in the capability to envision what hasn't already emerged in the specific domain or market under investigation. Hydraulic and electrical steering have been already successfully adopted as standard solutions in the aircrafts domain. The analogy suggests that their emergence is expected to happen also in the automotive industry in the next future, in order to further reduce the constraints of layout design in the front part of the car, thus allowing the introduction of devices that are now too much room demanding. Please notice that hydraulic assisted steering represents a different solution than a pure hydraulic steering.

This last consideration is part of the activity of **checking the coherence of the envisioned solutions with the available information about the context**. Indeed, the application of analogy and adaptation for the generation of envisioned solutions can produce outcomes that are not necessarily meaningful for the specific domain of the investigation. Thus, it is necessary to rescan all the envisioned solutions generated during the previous step of the approach in order to better understand which one is more suitable to address the future needs emerging from the context. The following considerations aims at clarifying the overall logic behind the last step of the FORMAT approach for envisioning solutions as directions for further technology development.

Getting back to the envisioned solutions concerning the evolution of the steering wheel, it is possible to notice, with a broader perspective, that car engines are now evolving towards hybrid technologies, thus involving both the presence of new and room demanding devices for both storing and managing the distribution of electric energy. This overall trend for the market shows that it is necessary to reduce the room occupied by other devices in order to keep the overall size of cars, thus confirming the need of more evolved solutions as the one envisioned before (hydraulic and electric steering). On the other hand, the hybrid technology diffusion also shows the enhanced "electrification" of cars, suggesting that the electric steering has more chances to be applied by the automotive industry than the hydraulic one, due to the overall trends currently characterizing that domain.

As mentioned at the beginning of this white paper, this approach is just part of the whole stage aiming at better understanding what the future of the technical system under investigation will be. By means of the combination of the results of the presented solution-based approach with the ones obtained from the problem-based approach and the quantitative analysis, the forecasters are capable of building a more refined and complete vision about the future.

References

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