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Relating properties and functions from patents to TRIZ trends

P.-A. Verhaegen [a,*], J. D'hondt [a], J. Vertommen [a], S. Dewulf [b], J.R. Duflou [a]

[a] Centre for Industrial Management, Department of Mechanical Engineering, K.U. Leuven, Belgium
[b] CREAX N.V., Ieper, Belgium

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ABSTRACT

TRIZ trends describe the evolutionary status of a system by identifying the trend phases, and assist in predicting improvements by identifying evolutionary potential. This process encompasses analyzing and categorizing patents in known trend phases, relying on intrinsic skills of a TRIZ expert, and depicting the results on an evolutionary potential radar plot. To structure this approach, an algorithm is proposed that, through patent analysis and word category identification, extracts information concerning product properties, which relate to trend phases. Allowing controlled and repeatable measurements of trends, this algorithm aims at reliably identifying the evolutionary potential and possible improvements to this product.

1. Introduction

1.1. Technological forecasting

Technology Forecasting (TF) indicates all processes to anticipate the generic or specific direction of technological change of a product or family of products, primarily focusing on inventions and innovations. Generally, TF has four roles towards steering R&D and technology related decisions on a managerial level [1]. However, for the research underlying this paper a more restricted definition of TF is used, limiting its role to monitoring specific technology and planning for technology development.

Besides the well-known and widely used trend extrapolation and Delphi methods, there exists a multitude of other TF methods, which can be categorized as quantitative versus qualitative, and as normative (goal-oriented) versus exploratory (extrapolation of current technological capabilities) [1,2]. TRIZ trend analysis can be categorized as being quantitative, as it is based on the observations of metrics, such as the number of patents. Although TRIZ trends are certainly among the more formalized and quantitative methods, it must be noted that the gathering of the underlying metrics relies on TRIZ expert skills. This research aims at further formalizing and quantifying this approach through reliable TRIZ trend measurements by analyzing a patent set associated to the product.

1.2. TRIZ

TRIZ is the Russian acronym for the Theory of Inventive Problem Solving, and encompasses a series of tools and a methodology for generating innovative ideas and solutions for problem solving. It was formed through the systematic analysis of what TRIZ practitioners estimate to be one and a half to three million patents, in which the applied innovative solutions were mapped onto a small number of extracted inventive principles.

TRIZ is based on three postulates [3,4]:

- The Postulate of Existing Objective Laws states that engineering systems evolve according to a set of laws.
- The Postulate of Contradictions states that, in order to evolve, an engineering system has to overcome one or more contradictions.
- The Postulate of the Specific Situation states that the problem solving process should take into account the specific problem peculiarities.

Derived from this patent analysis and based on the postulates, a set of TRIZ tools was conceived, of which the most popular are [5]:

- The Contradiction Matrix to solve technical contradictions;
- The Separations Principles to solve physical contradictions;
- Substance-Field (SU-Field) modeling and the Inventive Standards to transform technical systems;
- ARIZ as a list of logical procedures for eliminating contradictions;
- TRIZ trends as a system of laws that govern engineering system evolution.

* Corresponding author.
E-mail address: PaulArmand.Verhaegen@cib.kuleuven.be (P.-A. Verhaegen).

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It should be noted that, in contradiction to the other TRIZ tools, TRIZ trends are almost solely based on the Postulate of Existing Objective Laws. Some of the other tools are also based on this postulate, and trends can be easily identified in these tools, e.g. the Inventive Standards—Class 2: Evolution of Systems [4,5].

Several examples of the integration of TRIZ in the conceptual and embodiment stages of the classical design process exist [6]. In combination with Quality Function Deployment (QFD), TRIZ allows to focus efforts on the relevant mechanism identified through analysis of the customer's needs [7,8]. Other literature has illustrated the complementarity of TRIZ with Axiomatic Design [9,10] and Robust Design [11], and the integration of TRIZ with DFMA, resulting in a methodology in which DFMA analysis is used to evaluate TRIZ generated alternative solutions [12].

1.3. TRIZ trends

Classical TRIZ identifies eight laws of development of systems, subdivided in static, kinematic and dynamic laws [4]. The three static laws enumerate the necessary criteria for the viability of technical systems, and describe which parts a system must contain, and how the periodicity of operation of these parts must be coordinated or purposely uncoordinated and that these parts must freely conduct energy through the system. The kinematic laws govern the evolution of technical systems regardless of system-specific conditions. These laws state that, as a system evolves, it increases its degree of idealness, and that development of the system's parts occurs unevenly, resulting in new technical and physical contradictions. The third kinematic law expresses that, when a system exhausts its evolutionary potential, it is incorporated in its super-system as one of its parts, and as a result it can further evolve. The more system-specific dynamic laws indicate the tendency of the working units to act on a smaller scale, and also point towards increasing (electro-magnetic) S-Field involvement. A hierarchical overview of these laws can be found in [13], which divides these laws into laws of system organization and laws of system evolution. Some literature also explicitly states the S-curve law, as the cycle of birth, growth, maturity, and decline which every technical system goes through [14]. The above laws are in fact hypotheses, and Savransky [5] (p. 96) proposes to name them trends because they were obtained through induction of patterns in patents, and no formal proof has been given yet. As the majority of literature refers to these hypotheses as laws, and to the lines of evolution as trends, this article uses this nomenclature.

A number of these laws include more specific sequences of transitions or trends, indicating how a system or its parts evolve over time [13]. An updated, non-hierarchical list of thirty-five trends, incorporating new domains and reflecting new innovative solutions, can be found in [15]. These more specific trends should be regarded as the evolution of general properties of the parts of the system. This research focuses on these updated trends as this allows for a more actual and specific categorization, and this is considered more practical in predicting future improvements of a technical system through evolutionary potential. This concept of evolutionary potential can be defined as the difference between the limits of each of the evolution trends and the relative maturity of the current system with respect to these trends [16].

The following section gives an overview of the related research on technological maturity, evolutionary potential, patent analysis and the integration of TRIZ in the design process. The third section describes the proposed methodology, while the fourth illustrates this methodology with a case study. The final section formulates the conclusions.

2. Related research

The relationship between the technological maturity, or the lifeline of technological systems, and the four metrics proposed by Altshuller [4] was validated on a case study basis in [17–19]. To circumvent difficult to measure metrics, such as the profitability or the performance metric, these studies often use indicators, such as the number of patents that used the technology, or do not take these metrics into account. Besides Altshuller's four metrics [18] also reviews the number of cost reduction related inventions and the number of symptom-curing related inventions as technology maturity metrics. This research determines the overall-maturity of a product family on an S-curve, but does not indicate which trends have more evolutionary potential. It is therefore less specific as input to the planning for technology development.

Other research by Cavallucci [6] proposed and validated the possibility to incorporate the eight original Altshuller's laws of development in the design process on a manifold case study. For each of the eight laws, the product under consideration was positioned on a zero to three scale, a process heavily relying on the expert's intrinsic TRIZ skills. Based on TRIZ and domain knowledge, the conclusions concerning the development potential can be translated into specific directions for future improvements of the manifold. It was also concluded that the difficulties a company faces when integrating this approach, are mainly related to the building up of TRIZ competence and the time and money required to do this.

Building on Cavallucci's research, the proposed approach addresses these difficulties by automating the process of positioning the product on the trends. Furthermore, by using updated and more specific trends, the interpretation of the evolutionary potential and the drawing of conclusions concerning possible improvements is facilitated.

In [20] and [16], Mann and Dewulf propose the concept of evolutionary potential, which is similar to the approach proposed by Cavalucci, but uses the more specific trends, allowing for a more actual and specific categorization.

As stated in the introduction, TRIZ is based on the results of manually analyzing millions of patents. To actualize this information, automatic patent analysis and classification systems can be used. However, these systems are based on technology-dependent schemes, such as the International Patent Classification (IPC), and fail to satisfy TRIZ user requirements. TRIZ users are more interested in analogous inventions in other fields that solve the same contradiction using the same generic inventive principles. Loh and He [21] proposes an automatic patent classification to categorize patents in six selected inventive principle classes, and also evaluates the performance of different clustering algorithms on this task. He and Loh [22] proposes a text-based expert system for TRIZ-based patent classification according to Inventive Principles, which are grouped in 22 new classes based on distinctiveness, and text and meaning similarity. Other methodologies allow to identify the architecture of the invention by identifying the components, their compositional relationship, and functional interaction [23,24].

3. Proposed methodology

To further formalize and quantify the process to obtain the evolutionary potential, this research proposes an algorithm and framework that, through patent analysis and identification of adjectives, can extract information concerning the properties of a given product or product family, which in turn can be related to particular trends or trend phases. Allowing for more controlled and repeatable measurements of TRIZ trends, this algorithm can be incorporated in the product design specification phase to support