Innovation through pertinent patents research based on physical phenomena involved

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Abstract

One can find innovative solutions to complex industrial problems by looking for knowledge in patents. Traditional search using keywords in databases of patents has been widely used. Currently, different computational methods that limit human intervention have been developed.
We aim to define a method to improve the search for relevant patents in order to solve industrial problems and specifically to deduce evolution opportunities. The non-automatic, semi-automatic, and automatic search methods use keywords. For a detailed keyword search, we propose as a basis the functional decomposition [1] and the analysis of the physical phenomena involved in the achievement of the function to fulfill.
The search for solutions to design a bi-phasic separator in deep offshore shows the method presented in this paper.

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1. Introduction

Some solutions to industrial problems can be found by looking for knowledge using different information sources such as patent databases, journals, etc. as well as different search techniques to find innovative ideas such as: brainstorming, benchmarking, Delphi 6 sigma, checklists, etc [2]. Patents are a large source of free technical knowledge that describe, explain and reveal current technologies used, and provide solutions to problems. White [3] states that patents disclose information not published in scientific journals or conference proceedings. Eighty percent of the information contained in patents is not published elsewhere.

Different methods are used to find knowledge about patents. Computer tools partially or completely limit human intervention. They use techniques such as text mining, data mining, ontologies, natural language processing (NLP),etc. in order to satisfy multiple goals such as: problem solving, technology forecasting, classification of patents in categories, network, citations occurrence, trends etc. Despite the reduction of human involvement, many troubles are still present, i.e. in the semantic analysis: homography, polysemy, synonymy, fuzzy nature of the relationship between words in human language, partial synonymy, the hierarchical relationships (hyperonymy and hyponymy), and use of some jargon [4]. In traditional keyword search methods, the search is made using the keywords associated to the problem; then an analysis must be done manually. Finding relevant results depend on the user's experience and skills. Different reasons show that this method cannot be considered exhaustive, i.e. the level of detail descriptions of patents, inaccurate terminology, multiple languages etc [5].

Our methodology aims to improve the effectiveness of traditional keyword searches using functional and physical analysis (functional flow path, section 3.1). Performing a function involves an energy which is converted and transmitted to a component that will produce an effect [1]. Exhaustive analysis of all possible initial energy, transmitted energy, and the phenomena of physical conversion allows us to select the physical effects. These physical effects comprise the relevant parameters. The energy conservation laws allow us to validate these parameters and their relevance, and to define desired behaviors. The relevant parameters and the searched behaviors will structure the keywords to be used.

Then we generate an iterative keyword database that, at each research, grants finding new technological keywords that will be used to refine the search. Based on the findings, we perform a classification structured by keywords in a discovery matrix form. The concepts found will be analyzed from the evolution trends of the TRIZ theory. The empty cells in the matrix outline new opportunities for innovative solutions.

The rest of the paper is organized as follows; in section two we explain the work in relation with patent analysis and situate the proposed methodology. In section three, we present our method of innovation through the description of the functional analysis, retrieval of relevant physical phenomena and relevant parameters, followed by the classification method. Section four will show the application case in a bi-phasic separator in deep offshore. We will finalize with the conclusion and perspectives.

2. State of the art

Two primary questions are presented in order to build the state of the art and position our method. First, "how" (Fig. 1) i.e. the methods and techniques used. Then, "why" (Fig. 2), specifically, the objectives frequently found in the literature.

Text mining has been used to extract significant-rare keywords by Li [6], the selected words are those less frequently used by scientists and technologists. Yoon and Park [7] use this technique to transform raw data (patents expressed in text format or in natural language) into structured data. They exploit it as an extraction tool, to identify keywords and to measure similarity between patents. Choi and Park [8] used the text mining technique for the analysis of Subject-Action-Object structures (SAO), ranked them by similarity, and identified them by the type of technological implications.

Data Mining techniques and NLP are used for data extraction and classification of patents in several categories of inventiveness [9]. Yoon and Kim [10] propose a method to extract binary relations between patents through NLP; then they find out specific trends and phases of evolution trend (TRIZ evolution trends[7]). The tool, "TrendPerceptor" [12] is based on this method.

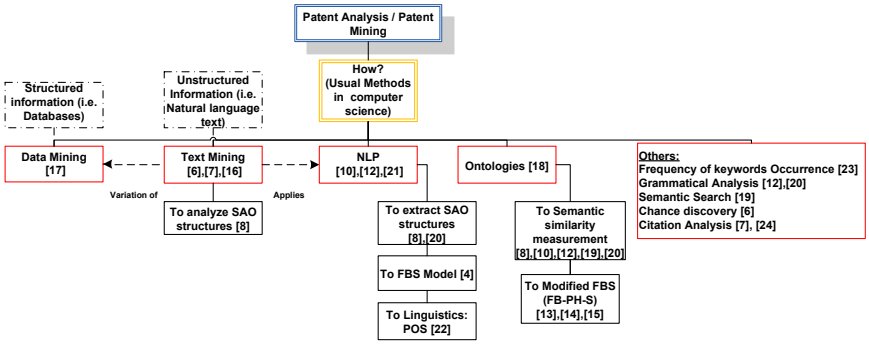

Fig. 1. Synthetic map of techniques found in literature. A double border box indicates the main subject studied. A dash line arrow designates a relationship and a dash-lined box stands the type of information commonly used.

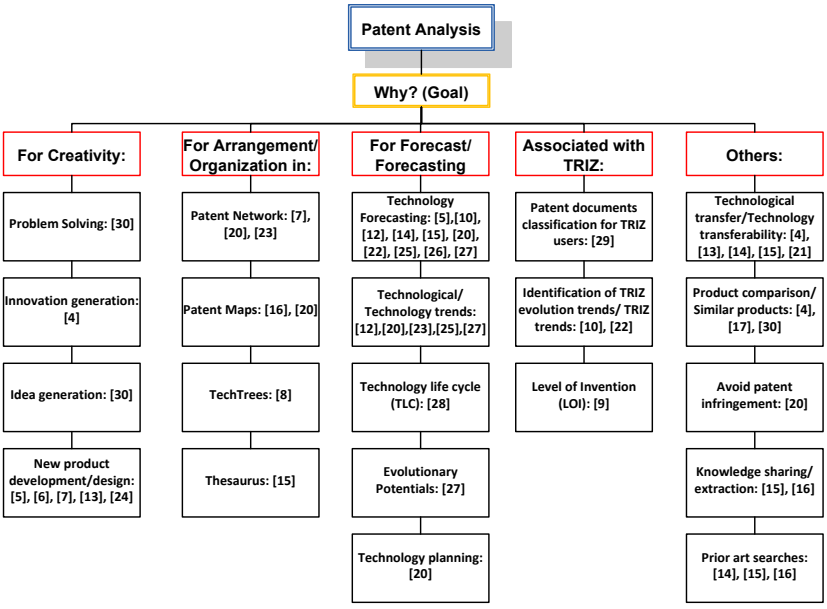

Fig. 2. Overview of the common objectives in patent analysis. A double border box indicates the main subject studied.

Ontologies [e.g. Function-Behavior-Structure (FBS)] are used by Russo and Montecchi [13,14,15]. They introduce physical phenomena in order to complete keywords. In their method, they begin with the definition of the product function and, using three creative approaches (Linguistics, Engineering and Multi-Vision), they list different possibilities for the same function, which will be translated into keywords and combined with additional keywords from a physical effects database. A specific algorithm handles these keywords and creates a group of queries to identify essential patents in order to achieve a state of the art. The database of the physical effects used by the authors is obtained by merging different knowledge bases of existing physical effects data.

3. Proposed method

The different methods mentioned above are based on the initial keywords to launch a search. The relevant results are found using semi-automatic or automatic methods. The final analysis of the semi-automatic case is formed with one or more expert designers.

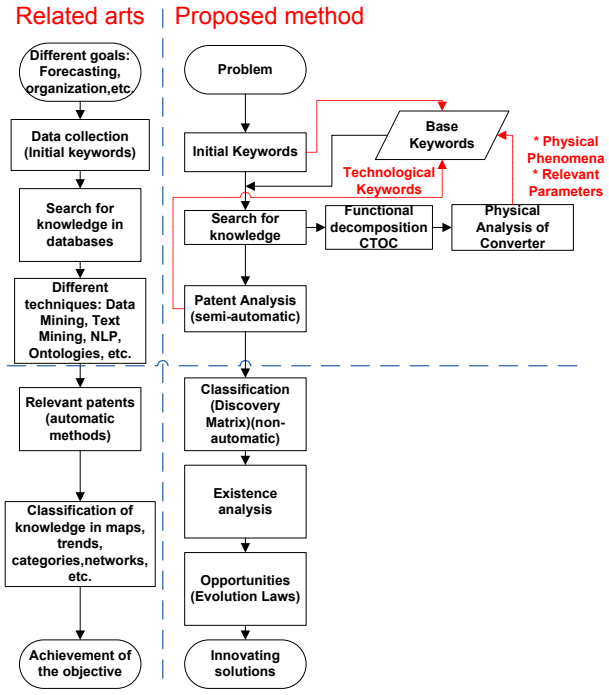

Fig. 3. Synoptic of positioning of proposed method. Dash line arrows indicate the entrances to the keyword database.

The proposed method (Fig. 3) is based on a detailed analysis of the function to fulfill. The exhaustive search for relevant keywords begins with an analysis of the required functional flow to carry out the function. The expected operation will be described by a functional analysis that will lead to the selection of physical phenomena imposed or implied. The physical phenomena, the improvement techniques and related keywords are the basis of knowledge. Functional decomposition allows us to access different keyword fields of initial keywords. These keywords come from different types of converters which can be selected (Section 3.1), permitting us to search for patents in different fields. The search for patents from keywords listed in the knowledge database is then carried out using traditional databases of patents. Our Research is oriented and framed. The designer selects and classifies relevant patents seeking to deduce development opportunities to move toward innovative solutions.

3.1. Energy based functional decomposition

We use the functional and physical analysis to associate keywords with relevant physical parameters. Pailhès [1] proposed the said functional analysis CTOC (Converter, Transmitter, Operator, Control / Command). For a given function, it is possible to distinguish four main elements for the implementation of the action.

The converter changes the available energy into usable energy. The transmitters transmit and/or adapt this energy to the operator who performs the action. The components of control/command provide the required performance. The functional flow is constituted by the delivery of power through the components. The functional flow and the components that it crosses are necessary and sufficient for the realization of the function (Fig. 4).

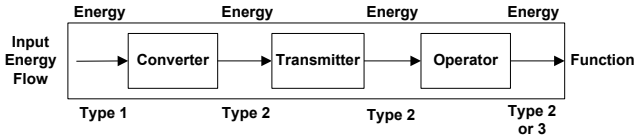

Fig. 4. CTOC decomposition to perform a function.

The final energy that perform the action may be different from the outgoing converter energy. The operator itself is an energy converter if the energy which performs the action is different from the energy transmitted by the transmitter. For energies of identical input/output, we can use different types of converters. These findings become a source for expressing new keywords that will allow the eventual patent search.

The use of functional decomposition allows us to focus and direct the search by defining keywords related to the associated physical phenomena. These keywords come from physically analyzing how converters function thus suggesting future possibilities at to the evolution of other relevant physical parameters. In such cases, they become keywords for further research further complementing the keyword database.

3.2. Converters and Physical phenomena

It is possible to express the functional flow associated with conducting the function in terms of energy flow. This simplified process allows us to reconcile the design with physics based approaches in which the input or output energy flow is expressed by energetic power (a product of two characteristic variables, Table 1).

The study of conservation laws in converter components allows us to define relevant parameters. These variables are the first keywords. We then look for the relevant physical

parameters involved in the conservation laws (energy, material, momentum). The names of the physical phenomena involved in these laws establish new keywords. The study of these laws enables us to define the possibilities for increasing the efficiency from the evolution of the parameters. The techniques used to vary the parameters also compose new keywords.

3.3. Methods and classifications

The database keywords (physical phenomena and improvement techniques) allow us to research knowledge from the commercial databases. We only use Espacenet (European Patent Office), which contains over 60 million patent documents from 80 countries [3]. From that point a structured analysis allows us to classify relevant patents by a tool named "Discovery Matrix".

The discovery matrix is a tool that allows us to organize the results in a table based on viewpoints defined by the user. In Fig. 5, the matrix is constructed by crossing the technological systems and the keywords associated with the types of converters to physical phenomena. Each converter includes relevant physical parameters (RPP). Each RPP can be linked to one or more physical phenomena (PP). The improvement of each PP can then induce specific techniques (RT). Each relevant patent is thus classified. The first evolution opportunities are found in the empty cells, which mean that the corresponding concept does not yet exist.

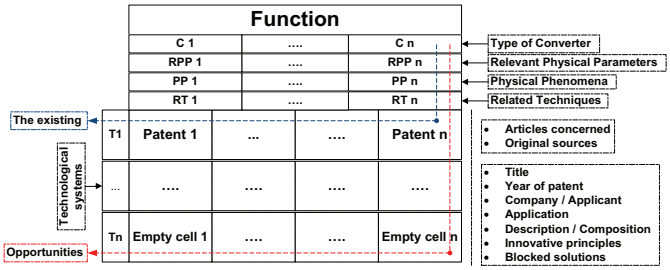

Fig. 5. Concept of discovery matrix.

We can also exploit the matrix from the laws of technical system evolution, but that is not the purpose of this article.

4. Application case: Biphasic separator

The application case relates to a bi-phasic separation system in deep offshore. The oil and gas produced from wells in producing fields form a bi-phasic mixture. We take the separation case of oil and gas when the gas flow is the most important and the oil is in the form of droplets. We are looking for concepts to enable the functioning of "separating oil from gas"; this is the main function of this study.

We begin with the keywords of the initial problem: « Gas; liquid; separator (device, apparatus …) ». Several technological systems are identified, i.e. cyclone, hydro cyclone, blades, plates, helices… Our goal is to further develop those systems.

To perform the main function, we must then find components linked to the movement of the functional flow (Fig. 6), the final goal being to define all physical phenomena to produce a force (F), which will displace (with velocity V) droplets independently of the gas flow.

Fig. 6. Decomposition of a system applied to a bi-phasic separator.

Consider the example of a centrifugal force; several concepts are known: cyclones, helices, blades etc. We will base our example on cyclones. Available energy (input) is electrical energy. The classic converter that can convert electrical energy into fluid energy is a bi-phasic pump. The bi-phasic conduit is the transmitter. Finally, the operator is the element that will help transform the fluid power (qvp) in radial displacement of droplets (VF), which is the role of the cyclone. The cyclone, which too is a converter, will be explored for possible future evolutions.

In the operator, the bi-phasic flow has a circular motion and the liquid droplet undergoes a centrifugal force, which moves it towards the periphery where it is recovered (Fig. 7).

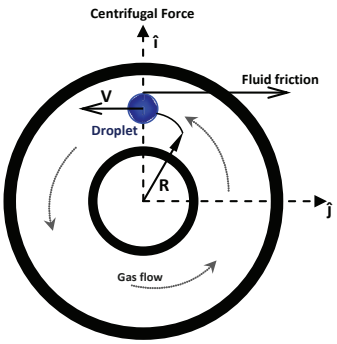

Fig. 7. Biphasic separation concept by centrifugation.

Table 1. Examples of relevant conjugate variables.

Type of energy	Temporal variables	State variables	Energy flow (power)
Mechanical (translation)	Speed (V)	Force (F)	V·F
Mechanical (rotation)	Rotation speed (ω)	Couple (C)	ω·C
Hydraulic/pneumatic	Volume flow rate (qv)	Pressure (p)	qv·p
Thermal (sensitive)	Capacity flow rate (q Cp)	Temperature (T)	q·Cp·T
Thermal (Storage)	Flow rate (q)	Internal calorific value (PCI)	q·PCI
Electrical	Current (I)	Electrical potential (U)	I·U

The fundamental principle of dynamics (law of conservation of momentum) is written on a droplet:

$$\sum \vec{F} = m \cdot \frac{V^2}{R} \vec{i} + m \frac{dV}{dt} \vec{j} \quad (1)$$

ΣF includes the friction of the liquid/gas contact with the cyclone and the weight. In order to visualize the relevant parameters, we express the mass m of the droplet as a function of the diameter d and the density ρ:

$$\sum \vec{F} = \frac{1}{6} \rho \pi d^3 \frac{V^2}{R} \cdot \vec{i} + \frac{1}{6} \rho \pi d^3 \frac{dV}{dt} \cdot \vec{j} \quad (2)$$

Two parameters from the centrifugal force are relevant – the velocity (V) and the diameter (d) of the droplet. If we want to increase the centrifugal force, we can increase the speed and the diameter of the droplet. The coalescence of droplets carried by the fusion droplets approximation, vibration or collision, allows increasing diameter. This analysis gives us the physical keywords, centrifugation and coalescence, and the improvement techniques, approximation, collision and vibration.

An initial search with the keywords "gas, liquid, separator" yields about 17,720 patents. If we want to narrow the search using the logic of the converters, we include the word "cyclone", we now have 940 patents. To focus the search, we use the new keywords found by means of the functional decomposition.The research is then launched using the patent database Espacenet, and incorporating our keywords database. Four results are found, containing the keywords "gas; liquid; coalescence; cyclone; separator". In particular, the patent CN202052637 uses a hybrid technique of centrifugation and gravity chute to separate liquid droplets from the gas stream (Fig. 8). We notice that the words "gravity and collision" of our database were not used and only the words "coalescence and cyclone" were enough to find them.

Take for instance the fourth patent (US4154972). This patent was not found among the 940 patents that include the keyword cyclone (due to search engine database). The concept is hybrid, a cyclone, and a high voltage electrode to promote coalescence.

So a new search is performed with three words "gas; liquid; coalescence" (led 183 patents). In this case, we note for example, that the tenth patent (CN2026666475) uses high resonant frequency to achieve coalescence. So it becomes clear that the keyword coalescence has led us to new fields of research, thus demonstrating the robustness of the method.

Note that the keywords “helices” and “coalescence” do not give results (empty cell). In any case, it is advisable to explore possible solutions in this area.

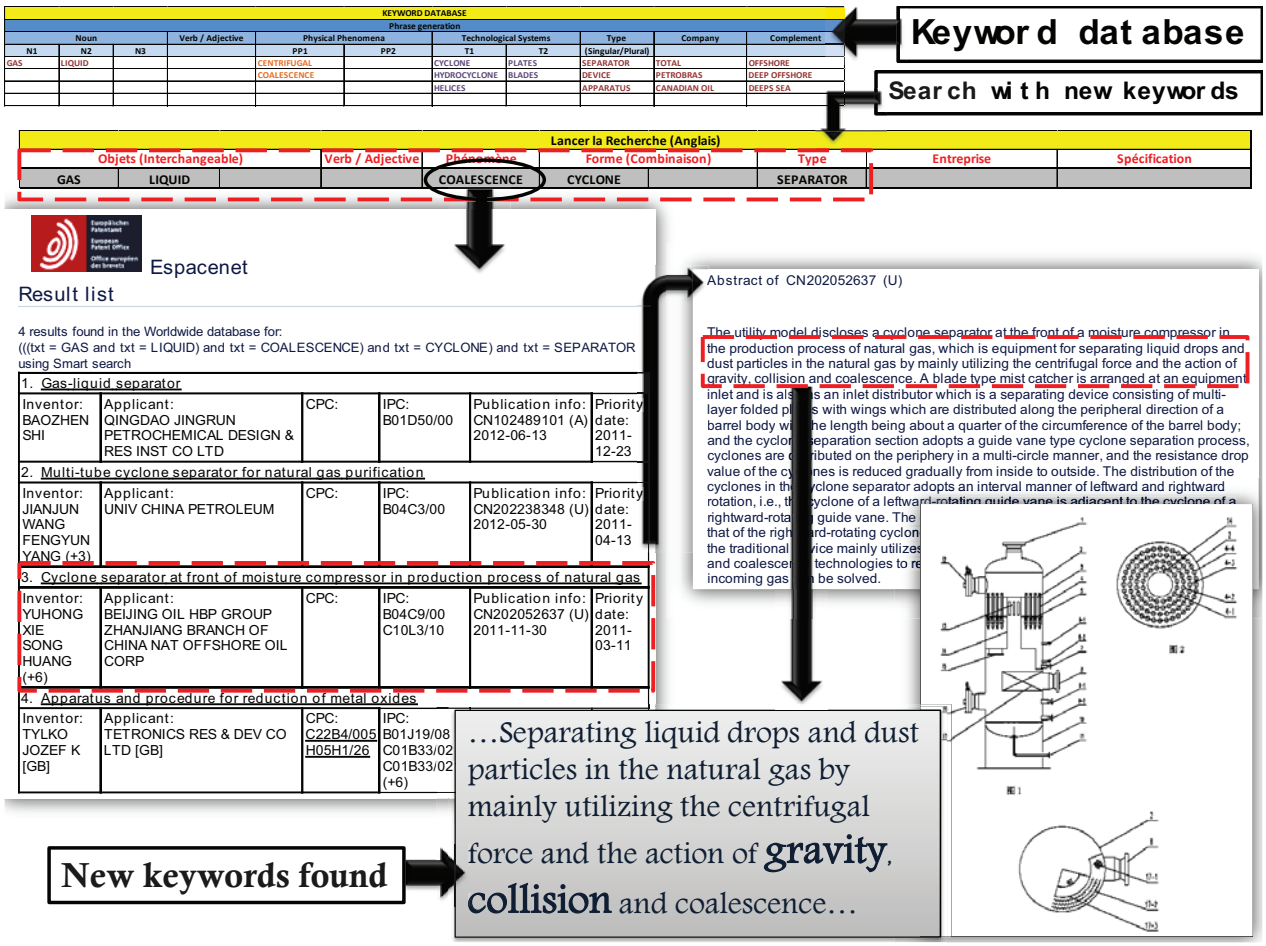

Fig. 8. Application example, research by exploiting new keywords.

5. Conclusion and discussion

We have proposed an improved method for determining keywords for patents search. Keywords are defined by physical and functional analysis of the possibilities of achieving the desired function. An energy vision (CTOC method) is used to define a functional flow from the notion of converter and energy transmitter. We deduce words related to the relevant parameters and improvement techniques of forces involved.

An application to a bi-phasic separator shows the robustness of the method from centrifugal systems. We could generalize the search by changing the type of separation force. An exhaustive vision can be conducted from the gravitational to electromagnetic forces.

The evolution opportunities found refer to empty cells in the discovery matrix that are concepts not already protected, but maybe feasible. We can also study patents found with the filter provided by the laws of technical system evolution and identify future trends. We envision building database converters and associated physical phenomena. These are perspectives for our work.

We did not use the methods described in the first part of this paper. Their use would have yielded a greater and more exhaustive number of patents related to the initial problem. The use of functional decomposition (CTOC) defines the new keywords that will allow us to select relevant patents permitting us to obtain new patents in unexplored fields, by using initial keywords. The thoroughness of the search is dependent upon the selected databases and their search engine. In this paper we have restricted our usage to the search engine and database of Espacenet.

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