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The combination of the disciplines of Techmining and semantic TRIZ for better and faster analyzing technology evolution

PhD dissertation

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Acronyms Legend

AGP. Antibiotic alternative Growth Promoter

CCD. Coupled charged diode

DRE. Digital rectal examination

DSSC. Dye sensitized solar cell

EPCA. Early prostatic cancer antigen

TFT. Thin film transistor

LCD. Liquid crystal display

LED. Light emitting diode

LiFePO4. Lithium iron phosphate

LiCoO2. Lithium cobalt oxide

LiMn2O4. Lithium manganese oxide

LISICON. Lithium super ionic conductor

miRNA. Micro ribonucleic acid

PCA3. Prostate cancer antigen 3

PET/CT Positron emission scan with computerized tomography

PSA. Prostate specific antigen

SAO. Subject-action-object

Techmining: the application of text mining techniques under the knowledge of technology management

TRIZ. Russian acronym of Inventive problem-solving theory

S-S TRIZ. Semantic and syntactic TRIZ

Summary

The purpose of the present thesis is to explore and to demonstrate how the combination of two methodological approaches, text mining plus the systemic vision of TRIZ empowered by semantics, can bring a larger and more comprehensive analysis of the evolution of a technology. Both approaches had been not combined before the first of the four papers constituents of the present thesis based in a compendium of publications. However, this combination applied to the evolution of technologies is increasingly being published in the scientific literature. Such combination shows a second benefit in the form of an improvement in accessing and connecting knowledge from disparate scientific literatures in a systematic manner.

The common element in all these papers is the use of the technology mining approach, 'Techmining', the application of text mining techniques based on technology management knowledge, combined with the use of semantic TRIZ, the advantage of syntactic applied to the systemic vision of TRIZ.

These papers show that a better analysis of evolving technologies, e.g. by profiling technologies from a systemic point of view or, a better access to knowledge, e.g. by semantically connecting concepts with meaning, can be achieved. The research on applying the combination of these approaches to scientific and technological information analysis explores the advantages and new possibilities for technology trends assessment as well as the semantic connection of concepts which represents a change in the way information research can be done. The different applications of the aforementioned combination are explored by means of the here presented articles. The structure followed in this research is the collection of three papers published in international academic journals indexed in the most prestigious databases and one chapter in a proceedings book of an international congress. The attached articles show the research undertaken to demonstrate the aforementioned benefits of the proposed combination.

Despite it can be found many methods and approaches about the assessment of the evolution of technologies, distributed across the literature, there is still a need to better understand which technologies may emerge, which may evolve faster and at what pace can they reach the market. The combination of the Techmining approach and the semantic TRIZ approaches allows understanding the trends enriched with a systemic vision of the links, functions, and influences of constituent and enabling elements of a technology. Such systemic link of elements with its components and ecosystem also allows for a multi-dimensional view of a technology and further reduces the uncertainty to preview the progress of a technology.

The papers presented in this dissertation are based on the combination of the TRIZ methodology, the techmining approach and the semantic TRIZ approach, applied to different technologies in different domains, to proof the advantages and implications of the combination. The articles try the different interactions of the combined approaches, applied to the assessment of different technologies, such as lithium batteries for the electric car,

a medical case linked to a disease known as Ménière's Disease, the prognosis of prostate cancer, and the usage of probiotics as substitutes of antibiotics in the animal health. The wide range of technologies was selected to show the clear benefits of either combining the two approaches or applying predominantly one of them in the case of the Ménière's disease article. That difference in the nature of technologies also helped to better understand the systemic point of view of the technology, exploring new applications based on the general system theory from Bertalanffy as well as other related approaches about technologies.

Resumen

El propósito de la presente tesis es la exploración y la demostración de la combinación de dos enfoques metodológicos, la minería de textos y la visión sistémica de TRIZ reforzada con la semántica, pueden aportar un mayor y más exhaustivo análisis de la evolución de una tecnología. Ambos enfoques no habían sido combinados antes del primero de los cuatro artículos que representan esta tesis por compendio de publicaciones, aunque dicha combinación ha sido crecientemente publicada en la literatura científica, para múltiples propósitos desde entonces. Un segundo aporte proporcionado por esta combinación es la mejora de la capacidad de acceso al conocimiento y cómo ello supone un avance para el descubrimiento a través de literaturas no relacionadas "*disparate literature discovery*" de una forma metódica y científica.

El elemento común en los artículos aquí presentados es el aprovechamiento de techmining, esto es, la minería de textos con base en la gestión tecnológica, por ejemplo, mediante el perfilado de tecnologías, junto al enfoque de la metodología TRIZ potenciada por el análisis sintáctico y semántico, esto es, mediante la conexión semántica de conceptos, para un análisis más completo de la evolución tecnológica, proporcionando al mismo tiempo un acceso más racional al conocimiento.

La investigación sobre la aplicación de la citada combinación al análisis de información científica y tecnológica explora las ventajas y nuevas posibilidades en la evaluación del avance de la tecnología, así como la conexión semántica de conceptos que representa nuevas posibilidades en la forma en que la investigación textual puede hacerse. La estructura de la investigación aquí presentada se muestra a través de los artículos publicados en revistas internacionales de alto impacto y el capítulo de los 'proceedings' de un congreso internacional. Dichos artículos muestran la investigación llevada a cabo para demostrar los beneficios mencionados de la combinación propuesta.

A pesar de la gran actividad de investigación y de la existencia de varios enfoques para la prospectiva y la previsión tecnológica presentes en la literatura científica, existe aún la necesidad de entender qué tecnologías pueden emerger, pueden evolucionar más rápido y a qué velocidad pueden llegar al mercado. La combinación de los enfoques de minería tecnológica o techmining y TRIZ semántico permite entender las tendencias de

una tecnología dada, enriquecida con una visión de su sistémica, y teniendo en cuenta las conexiones de sus elementos y las influencias de sus elementos constituyentes. Tal conexión entre los componentes y su entorno permite una visión multidimensional de la tecnología reduciendo más aún la incertidumbre en la previsión de la evolución de una tecnología.

Los artículos presentados en esta tesis son aplicaciones y exploraciones de la combinación de mencionada, a diferentes tecnologías de diversos ámbitos muy dispares entre sí, con el fin de demostrar sus ventajas e implicaciones. Los artículos tratan las diferentes interacciones entre ambos enfoques de trabajo, aplicados a tecnologías como baterías de litio para los vehículos eléctricos, un caso médico ligado a una dolencia como el síndrome de Ménière, a la prognosis del cáncer de próstata y al uso de probióticos en la alimentación animal como sustitución de los antibióticos.

Este amplio rango de tecnologías ha sido seleccionado para mostrar las ventajas, de forma más objetiva, de la combinación de ambos enfoques o con predominancia de alguno en particular, como es el caso del artículo explorando el síndrome de Ménière. Estas exploraciones permiten también entender mejor el punto de vista sistémico de una tecnología, descubriendo nuevas aplicaciones basadas en la teoría general de sistemas de Bertalanffy, así como en otros enfoques relacionados.

Resum

El propòsit de la present tesi és l'exploració i la demostració de la combinació de dos enfocaments metodològics, la minería de textes i la visió sistémica de TRIZ, reforçada amb la sintáctica i la semántica, mostrant que poden oferir un abast més gran i més holístic en l'enteniment de l'evolució d'una tecnología. Tots dos enfocaments no habían estat combinats abans del primer article dels quatre que composen aquesta tesi, però creixentment combinat dins la literatura científica per a múltiples propostes des de la primera publicació. Una segona aportació proporcionada per aquesta combinació és la millora de la capacitat d'accés al coneixement, i de com això suposa un avanç en l'àrea de recerca a traves de literatures no relacionades "*disparate literature discovery*" d'una forma metòdica i científica.

L'element comú en els articles presentats en aquesta tesi és l'aprofitament de la mineria de textos amb base en la gestió tecnològica, '*techmining*', per exemple mitjançant el perfilat de tecnologies, al costat de l'enfocament de la metodologia TRIZ potenciada per l'anàlisi sintàctica i semàntica, mitjançant la conexión semántica de conceptes, per assolir un anàlisi més complet de l'evolució tecnològica, així com per a garantir un accés més racional al coneixement.

La investigació de l'aplicació de la combinació dels dos enfocaments a l'anàlisi d'informació científica i tecnològica realitzat, exploren els avantatges i noves possibilitats en l'avaluació de l'avanç de tecnologies, així com la conexión de conceptes que representa

noves possibilitats en la forma en què la investigació textual pot fer-se. L'estructura de la investigació ací presentada es mostra a través dels articles publicats i el capítol dels '*proceedings*' d'un congrés internacional. Aquests articles mostren la investigació duta a terme per demostrar els beneficis esmentats.

Tot i la gran activitat de recerca i enfocaments per a la prospectiva i la previsió tecnològica existents a la literatura científica, existeix encara la necessitat d'entendre quines tecnologies poden emergir, poden evolucionar més ràpid i a quina velocitat poden arribar al mercat. La combinació dels enfocaments de mineria tecnològica o '*techmining'* i TRIZ semàntic permet entendre les tendències d'una tecnologia donada, amb una visió del seu sistema, les connexions dels seus elements i les influències dels elements constituents.

Els articles presentats en aquesta tesi són aplicacions i exploracions de la combinació de la metodologia TRIZ, la seva potenciació mitjançant la semàntica i el techmining a diferents tecnologies de diversos àmbits, alguns molt dispars entre si, per tal de demostrar les seves avantatges i implicacions. Els articles tracten les diferents interaccions entre els dos enfocaments de treball, aplicats a tecnologies com bateries de liti per als vehicles elèctrics, un cas mèdic lligat a una malaltia com la síndrome de Ménière, a la prognosi del càncer de pròstata i en alimentació, a l'ús de probiòtics en l'alimentació animal com a substitució dels antibiòtics.

Aquest ampli rang de tecnologies han estat seleccionats per mostrar els avantatges de forma més objectiva, de la combinació de tots dos enfocaments o amb predominança d'algun en particular, com és el cas de l'article explorant la síndrome de Ménière. Aquestes exploracions permeten també entendre millor el punt de vista sistèmic d'una tecnologia, descobrint noves aplicacions amb base en la teoria general de sistemes de Bertalanffy així com altres treballs relacionats.

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Finally, I cannot forget to mention a deceased colleague of mine, Fernando Palop, whose determination and wisdom, initiated me in the research and in the information science and innovation. We both initiated a professional journey which finally brought me to the present dissertation.

Chapter 1
Introduction

TRIZ is a methodology derived from the inventive patterns found in thousands of patent documents, as well as its systemic view of technologies and their relationships. TRIZ states that technologies evolve following objective laws and not randomly and that the brilliant inventions use knowledge from outside its original industry (Altshuller, 1984) (Orloff, 2003).

Techmining is the application of text mining tools to science and technology information, informed by understanding of technological innovation processes. Techmining statistically analyzes thousands of records of articles or patents which bear title, abstract, affiliation, authors, keywords, citations, etc. By reorganizing all this content in a horizontal manner, it can create lists of top authors, top keywords, find relationships by cross referencing keywords with the authors or with institutions. Doing so it helps to define the 'who' and the 'where. Techmining is applied in much research trends and science policy evaluation by many research Institutions around the world. The techmining method itself is being further developed (e.g. Porter and Cunningham, 2005; Porter and Newman, 2011).

With the advent of computer advancement and the TRIZ conception of problem solving and problem-solution, Verbitsky coined the term 'Semantic TRIZ' in a seminal article in 2004. In the present dissertation, Semantic TRIZ can be defined as the application of syntactic and semantic mining tools to science and technology information, informed by

understanding about TRIZ and technology innovation processes (Vicente-Gomila and Palop, 2013).

TRIZ based syntactic-semantic indexing takes the TRIZ methodology concept of a system which delivers a function to an object, and applies it to substantives and its actions with their related direct complements and other grammatical structures. Such linking relationships can make logic sense and may link disparate literatures in the sense of knowledge discovery in the published related literature. It can help to create knowledge chains from known concepts to unknown concepts to the researcher. (e.g. Yoon et al., 2013; Vicente-Gomila, 2014).

Chapter 2
Research gap

Two elements mark the research gap for the present dissertation.

2.1. Is it an original approach the use of techmining and semantic TRIZ?

There is plenty of research activity using subject-action-object for technology analysis (e.g. Cascini et al., 2004; Moehrle et al., 2005; Choi, 2011; Kim et al., 2012; Vicente-Gomila y Palop, 2011; Choi et al., 2012a and 2012b; Yoon et al., 2013; Wang et al., 2015). The concept of subject-action-object, comes from the extension to written literature language structures of system-function-target, i.e. the system performs a function on the target. Recently, mounting research is being published for analyzing the technology evolution using the problem-solution semantic structure of subject-action-object. It shows plenty of publications with increasing presence in the international research and is being applied for technology policy and planning in different Countries. (Cunningham and Porter, 2006; Porter and Newman, 2011; Robinson et al., 2013; Zhang et al., 2014).

Porter and Cunningham (2005) mentioned the TRIZ methodology within their seminal book about techmining. Vicente-Gomila and Palop presented the first research combining techmining, TRIZ and semantic TRIZ at the EAEC world Congress in Valencia in 2011. Both authors presented their manuscript for revision in 2012 and the paper was published in 2013 in the journal Technology Analysis and Strategic Management.

Choi et al. (2011) presented the concept of analyzing trends by means of a network of subject-action-object (SAO), one of the key elements in semantic TRIZ. However, the

authors do not use any systemic approach, substituting a keyword analysis by a 'key-concept' analysis for statistically analyzing the relevance of nouns 'subjects' or 'objects'.

Choi et al. (2012a) use the SAO approach with a basis on the TRIZ methodology to apply the concept of functions as problem-solution to develop a patent retrieval system based on similarity of functions. More interesting is the work of Choi et al. (2012b), which uses text mining based on subject-action-object structures. By grouping similar SAOs, this work tries to relate components of a technology to their functional capacities in tree branched diagram for developing a quantitative technology tree 'Techtree'. The technology trees could be useful for technology planning. Choi et al. (2012b) also stress the advantage of using SAO for being less dependent of expert participation.

In 2013 PhD candidate Geneviéve Marie Garland presents her dissertation about combining techmining with TRIZ methodology, specially the part about laws of technology development, comparing both approaches to traditional forecasting methods. Ms. Garland applies the analysis to the textile industry. The dissertation was read at North Carolina University.

Wang et al. (2015) stresses the advantages of using a SAO approach in front of a keyword based technology trend analysis. The approach builds a technology roadmap by grouping the functions of a given component and plotting them against time. The approach builds certain organization in grouping the materials, technologies, components and goals as technology roadmap for identifying the trends in technology development of the die-sensitized solar cell (DSSC) system. However, the systemic approach is not adopted and thus the method offers a different approach and does not show understanding of the systemic dependencies among components and its impact in the development of a given technology.

Adner and Kapoor (2016) remark the need to know the dependency of the ecosystem elements of a technology to better predict the possible outcome in terms of possible evolution and future development. The combination of semantic TRIZ and techmining can help by systematically link elements and plot their trend to help see the evolution of constituent elements as well as elements of the environment (ecosystem).

Yang et al. (2017) recognize the increasing popularity of the SAO analysis, however they remark the lack of synonyms and the lack of criteria to select the appropriate SAO. The research offers a method to statistically analyze the SAOs extracted from a previous term clumping process (Zhang et al., 2014) and to rank existing SAOs accordingly.

Wang et al. (2017) enhances the morphological analysis with the contribution of a SAO analysis. By creating a matrix of technology components and the attributes of a technology, to find the gaps for technology opportunity. The approach takes advantage of the fact that the semantic capabilities allow to distinguish between SAOs denoting composition of a technology and SAOs denoting an attribute. These are two of the multiple dimensions that the state of the art of semantic analysis can perform. As in Wang et al.

(2015), the components of a technology are listed without a hierarchy among them or interdependencies and thus losing a key dimensional feature in evolutionary analysis.

Guo et al. (2016) goes further into the morphology analysis combined with the SAO analysis to enhance the former. This research uses the Stanford parser for extracting SAOs, based on the frequency. It also identifies subjects and objects to build an interesting table of component, materials and keywords associated to those extracted subjects. Then they use techmining to plot the combination of different subjects to detect which are present and which combination is not for identifying technology opportunities. This research is based on the abstracts not on the whole text or on the claims as in the third paper of the present thesis.

2.2. Can the combination of techmining and semantic TRIZ bring new insights to the exploration of science and technology?

The analysis of science and technology advance has been greatly systematized through the use of bibliometric tools and further advanced by the use of Techmining, a combination of text mining tools with the knowledge of technological innovation processes (Porter and Cunningham, 2005). However, the assessment of the evolution of emerging technologies, its progress and the possible shift to other new technologies, continues to be a subject matter of study.

The combination of the two approaches can bring advantages suitable for monitoring and analyzing the systemic interrelationship in the evolution of technologies.

In his review, when speaking about environmental scanning as a method for technology forecasting, Martino (2003) starts from a linear model of innovation, that is from theories up to commercial introduction for understanding technological progress. Some years before however, when studying technology measurement, (Martino, 1985) recognizes that technologies may have multiple parameters and that a higher level of aggregation is needed for the measurement of a given technology. Brian Arthur (2011) explains the birth of technologies as new combinations of existing components, showing new functionalities deriving of such new architecture or combination of technology components. An example could be, the case of Whittel and Von Ohain inventing the jet turbine out of by that time existing components in a singular order, and so giving birth to a breakthrough technology for air industry fan manufacturers in 1937. Sahal (1976) also recognizes the need to measure different parameters to better assess the progress of technological devices, but argues about the need for specialists to assess the key parameters in the technology being studied.

Altshuller (1984) explains that all technologies exist as a set of components organized to bring a main function and that the evolution depends on the pace of the different components. Their progress tries to bring the main function with less and less elements as

much as possible. Altshuller also coincides with Martino (1985, 2003) in the consideration of trade-offs or contradictions as a key step in the evolution of technologies. Bertalanffy (1970) suggest that for a better comprehension of the progress of technologies and products, it is necessary to consider them as systems, i.e. a set of components, their componentry and configuration of parts, and their relationships among its components or architecture. The need to assess technologies considering their configuration, their component architecture and interrelationships, their relationship with external elements along its evolution curve is a key for technology measurement. A broader interrelated framework is necessary to better understand technological progress and being able to measure it. Some authors also acknowledge the need for new techniques capable of analyzing technology architectures and systems (e.g. Dong and Sarkar, 2015; Rivkin and Siggelkow, 2007; Feng-Shang, 2011; Cunningham, 2009).

Therefore, the starting point of TRIZ is the analysis of technologies as systems. Also, how the system progresses to an ideal state, where all the benefits with no harm of that technology, is reached (Altshuller, 1984). As Bertalanffy (1970) reminds us, to deal with complex sets, or 'systems', one should consider aspects related to their number (quantity, citations, repetition, appearance, ...), but also their type and the relations of their constituent elements. Dong and Sarkar (2015) also remind of the significance of the knowledge embodied in the configuration of parts and sub-systems of a product as a way to better measure complex technology progress.

There is a need to further throw off some light on the systemic analysis of technologies, in order to better understand the technological progress or shifts to other new technologies.

The combination of trends analyzed by Techmining jointly with the syntactic and semantic approach of semantic TRIZ (Vicente-Gomila and Palop, 2013) could be a solution. Although initially coined by Verbitsky (2004), semantic TRIZ is the application of syntactic-semantic mining tools to science and technology, informed with the knowledge of the TRIZ methodology and the technological innovation processes. Semantic TRIZ should help to identify the hierarchy of main components as well as auxiliary components and the interrelationship among them. Complemented with Techmining, it could be able to assess their progress in its functions as a way to understand also their state in the S curves and their interrelationship within the system. The combination should help in the identification of parameters that best describe the technological progress (Feng-Shang et al., 2011).

The approach of assessing technology progress using a systemic point of view has been the subject of previous investigations. Yoon and Park (2005) combine techmining with morphological analysis in the study of a technology, taking into account their different parts or constituents, though not analyzing their interactions. Ma et al. (2014) apply the 'morphology analysis' to the components of the dye-sensitized solar cell. Koh and Maggee (2014) analyze a functional classification of elements contributing to a technology with their role, however such relationship is listed as a table without clear interaction

and lack of parameter interaction description as well as its implication in technology progress assessment. Li et al. (2011) propose a useful representation scheme for a technology, based on the components and their functioning relationships using the 'techspecs' concept ontology. Such representation introduces a hierarchy of components, mainly by layers more or less proximal to the whole artifact or technology. Yue et al. (2014) propose also a functional representation to assess the utility of a technology, extracting the parameters. Giordano and Fulli (2012) and Adner (2012) state about a systemic approach for evaluating business actors.

However, there is still a need to further explore the implications of a systemic point of view in the analysis of technologies, understanding the system and the ecosystem and the hierarchy of the elements in the system (Day et al., 2000; Adner and Kapoor, 2016; Vicente-Gomila, 2014).

The approach of semantic TRIZ allows to understand the hierarchy of components and its implication for studying their progress and then, applying techmining, the ability to analyze the trends and inducing its insights.

Chapter 3
Structure of the present thesis and research objectives

The main research objective of this dissertation is to explore the benefits of combining the approaches of techmining with Semantic TRIZ, by means of applying the combinations to the analysis and evolution of different technologies. Each of the chapters contribute with different approaches to this main objective.

The present study adopts the structure of a thesis composed by a compendium of published research articles from the department of Projectes d'Enginyeria. The structure of the chapters corresponds to the one suggested by the doctoral commission of the program in management and business administration belonging to the Universitat Politècnica de València.

It consists of three peer reviewed published articles and a fourth article published in the proceedings of an International Congress. One of the papers was published in *Technology Analysis & Strategic Management* in 2013, two of them in *Scientometrics in 2014 and 2017*, and the last at the congress of medical information in Brazil in 2014. Two 'hard' technologies and two more in the human, health and food fields, have been explored to demonstrate different benefits of using the combined approach.

In the first paper, the car energy storage system has been explored. The objective of this research was to identify emerging trends like LIFePO4 electrodes in lithium batteries and in lithium-air, and the increasing use of nanostructures in both types of technologies. Also, the increasing use of graphene was identified.

A second objective was to explain the 'why' and 'how' the different materials were used, helping to identify why the nanostructures were more used in the lithium ion than in the lithium-air technologies.

A third objective was to prove that the understanding of the system helped to identify current research challenges, as oxygen diffusion or ion conductivity, whose activity was subsequent analyzed by profiling the trends in such research challenges.

This research was presented in the 11 European Congress EAEC in 2011, and was complemented and later published in the international journal *Technology Analysis and Strategic Management* in 2013 Vol 25, nº 6, 725-743, DOI 10.180/09537325.2013.803065.

In the second paper, the exploration is related to the Ménière Disease. The objective of this research was to demonstrate the advantage and more deterministic method of combining semantic TRIZ with techmining, applied to the literature discovery. With a structured and logic cause linkage between concepts, the path to connect concepts of disparate literatures can be faster, more confident and with less expert involvement at least at the beginning of the literature based discovery (LBD) process.

The first objective was to show the logical path for a classical case in LBD: the Raynaud disease.

A second objective was to deploy the methodology to mining the full text of the literature about Ménière's disease, further extracting the identified causes of the disease.

The objective was to mine the literature of the cause' causes and so on to find the links until a disparate concept but logic as vector for treating the causes' causes were found.

This research appeared published in the international journal *Scientometrics*, April 2014, DOI 10.1007/s11192-014-1299-2.

In the third paper, the objective was to apply the combined approach to bring key insights to a medical community. In particular, by analyzing trends in the prognosis of prostate cancer.

A second objective was to profile the research in biomarkers for diagnosing prostate cancer, in order to identify the most promising biomarker and to inform a community of physicians about next trends based on the evidence of thousands of research papers.

A third objective was to complement the trend in biomarkers with the semantic answers from a broader scope and getting answers about how to detect prostate cancer.

This research was published in the proceedings of the third Medical Information Congress, Medinfor III Congress of 2014. For this research, the National Cancer Center from Colombia, the Federal University of Bahia in Brazil collaborated with the author. The proceedings were published with ISSN nº Medinfor III: 2358-3266.

In the fourth paper, the research objective was to apply the combination of techmining and semantic TRIZ to better and quicker detect shifts in the strategy of a company, by means of analyzing their patent claims.

The application of techmining to the 'claims' part of the patent documents, bring an advantage to the frequent practice of mining titles and abstracts. It is able to extract more terms not reflected even in the abstracts, and more strategic terms since these terms are part of the right any applicant is trying to protect.

The second objective is to apply semantic analysis to obtain the uses or applications of such strategic terms extracted from the claims, helping to understand what can be the benefits a given company is pursuing and finding reasons about the shift in the strategy of that company.

This research has been published in the international journal Scientometrics, Published online, March 2017, DOI 10.1007/s11192-017-2339-5, in collaboration with the competitive intelligence department of a National Agroindustrial Institute.

Chapter 4
Methodology

The combination of the two approaches can take several procedures as it can be understood from the compendium presented. One is to start with the techmining technique to identify emerging and prevailing technologies. The next step is to use the semantic TRIZ approach to dig further into the mentioned technologies in order to understand the 'why' and the 'how'.

Another methodological choice, starts with a systemic functional analysis, which helps to determine the systemic relevance of current research limitations, bottlenecks or deficiencies in the system. Immediately or in parallel, techmining confirms the trend of current research efforts on such bottlenecks or limitations, their authors or leading experts.

A more detailed general methodology which may vary depending on the research done in each paper, is:

The first step is to integrate the most cited and up-to-date reviews of a technology, to identify main research areas, existing current limitations and future areas of research. In this case, by analyzing scientific reviews covering the topic of the aforementioned technology.

The next step is taking advantage of the semantic analysis helped with a syntactic-semantic TRIZ based tool and its mereology capability, to complement the list of the main components, elements and materials of the system extracted from the first step.

The next step is to validate the systemic model with main functions and current limitations, with some of the leading experts in the research arena.

The fourth step is creating a list and a term clumping which will be further used in techmining.

This step consists in applying a techmining tool to obtain comprehensive citation trends on each component of the technology, with the understanding of the role of each component.

The last step is to explore the trends and role of the components in other component related technologies.

This methodology is further expressed through a case about dye-sensitized solar cell (DSSC) as a system, with implications of the hierarchy of components of the aforementioned system as well as its immediate ecosystem as a model for analyzing the evolution of technologies and its foresight.

4.1. Application of the methodology to a case: Analysis of *the DSSC system*.

This systemic focus, along with the combination of semantic TRIZ and techmining is demonstrated through the analysis of the dye-sensitized solar cell or DSSC. The DSSC is a system with components and interrelations among them. The study of the hierarchy and the interrelationship of such components may have an impact in the DSSC evolution and so it is worth to be studied. Furthermore, as the DSSC's technology components are shared by other technologies (Brian Arthur, 2011) maybe the development of such components occurs outside of DSSC more in consensus with the open innovation model.

4.1.1. Material and methods.

For the present analysis of the DSSC system, thousands of articles and patents from 2001 to 2013 have been mined, and semantically indexed. The purpose was to understand the trends of the constituent components of DSSCs, but also to explore if said components, do experiment a shift in their functions, usage and parameters, which either may consolidate the DSSC system, or may bring a new life for other energy alternative systems. The evolution of said components may hinder its original function in the DSSC system or, on the contrary, may advance it. The knowledge about the interrelations among the DSSC components should also help to identify several research challenges and bottlenecks of the complete system.

To understand the hierarchy of the components and their possible outcome in terms of research activity and technological progress, the first step is to understand the system, to elaborate a purposeful subject-action-object (SAO) chain map. Once known the relationship and, the parameters involved in such relationships, the next step is to check with the techmining approach. This combination helps to understand how these components evolve and may also explain why some components advance more than others, and what alternative systems may be competing.

To test the combination of the two techniques, a techmining exercise was developed following the nine steps of the decision phases and the techmining process (Porter and Cunningham, 2005). First step is to identify the issue to be analyzed; second step is to select the most suitable information sources; Third step is to define and refine the queries for data retrieval; fourth step is to group and clean the data; Fifth step is basic analysis, list profiling; Sixth step is to perform advance analysis, correlations, etc.; Seventh step is to represent the analysis; eighth step is to interpret the analysis; Ninth step is to utilize the analysis for decision making. Such process could analyze the state of the art and trends of the different components of the DSSC system. To define the search strategies, it has been considered to use some previous bibliometric work with the same topics, like in Ma et al. (2014).

The methodology applied is the one described previously.

Combined with the knowledge of the system and the hierarchy of elements in such system, all allows for a better understanding of the technology progress and a better interpretation of the different trends so far obtained with less expert involvement.

For the comprehension of the system, a purpose functional map of a DSSC system is presented in figure 1 based on the knowledge of TRIZ, the semantic TRIZ subject-action-object SAO modelling, and by reviewing several research papers and recent reviews about DSSC (Nazeeruddin, 2011; Chun-Pei, 2013), understanding about its materials, defects and or its current limitations.

The DSSC system depicted has been reviewed by the team of Nazeeruddin and Grätzel in Switzerland[1].

[1] Exchanged comments through emails during 2012

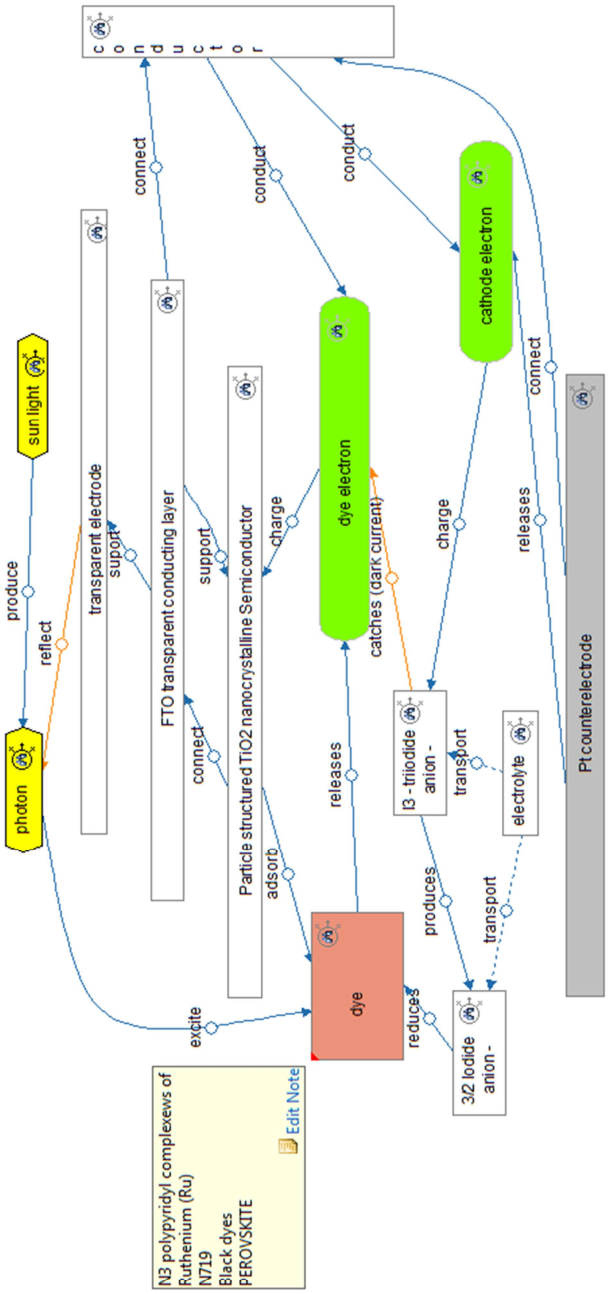

Figure 1. Functional systemic SAO diagram of the DSSC.

The diagram above represents the system model of a DSSC in where each arrow points from the 'tool' or function donor, to a function receiver or 'object' and represents a function in which the 'tool' changes, controls or maintains some parameter of the 'object' (Arel et al., 2002). The blue arrows represent useful functions, whereas the red ones are undesirable functions or shortcomings of the current system. The dotted lines are useful functions, although with a performance ranking below its satisfactory state; for instance, the electrolyte should transport the anions faster (Litvin, 2011).

The boxes are part of our system, the elements pertaining to said system. The hexagons are the elements which are out of our system, pertaining to the environment of said system, yet these supersystem or 'ecosystem' elements interact with our system elements. The ovals are the aim of the system, what the system is intended for, i.e. to satisfy a need of such 'object' to be modified, enhanced, etc. The diagram represents a 3D model of SAO chain structures.

In TRIZ methodology, the concept of an almost complete system has at least a source of energy, a motor, a transmission means, a tool and a control body. The tool of the system is directly responsible for changing some parameter of the object, the 'client' of the system. We should note that the 'object' of the system is the ultimate reason for the system to exist. For example, in a machine tool, the tool is the cutter and is directly responsible for machining the piece. The machine *exists* because we need to shape a piece in a repeatable and fast yet precise way. In a photo camera, the lenses are the *tool* shaping the image photons to cast the CCD or formerly the film (see figure 2).

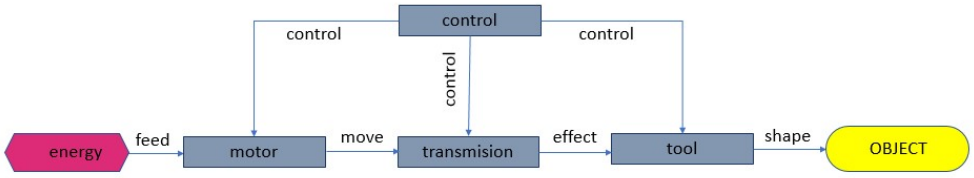

Figure 2. Hierarchy of a system.

According to TRIZ laws of evolution, it is easier to change the parts farther of the object, the oval in figure 2, rather than changing the tool (Vicente-Gomila 2014). The more internal and farther from the object the component within a system is, the easier to be changed. For instance, in the photo industry, filmmakers, camera makers, etc., all except lenses manufacturers were struggling to find a right position in the new digital market. In the system 'camera' all parts contribute to shape and register the shaped light. Here, the lens is the tool which directly changes the entering light. When the tool changes, the main principle of the system usually also changes, and this represents a major change in the technology. For instance, the lighting industry recently stopped the incandescent wire

(the tool producing the photons) in the search for other less consuming alternative tools for producing photons. Fluorescent lamps made some spare time for the coming of the LEDs. In these cases, the tool has been changed, carrying also major changes in the industry, but it kept without changes one of the components in contact with the environment (ecosystem) as it is the screw thread part. These inter phase components are also less prone to change due to their interconnected nature, which at the same time depends on standards and network effects (e.g. Grant, 2013). Sahal (1976) and Mc Nerney et al. (2011) try to assess the complexity of a product to predict its possible progress and evolution, however their definition of product relationship is based on design structure matrix or flow process rather into the functional relationship based on real parameter alteration and relative proximity to the 'client' or purpose of the technology, as in the present analysis. Wang et al. (2015) take advantage of lineal SAO structures for identifying development trends and to identify development problems. However, such approach does not provide a systemic vision capable to understand why some components may progress faster than others, do have a key role, or the hierarchy of the identified problems.

An example in the DSSC system, also illustrates these cited laws. Being the tool within the DSSC system, the *sensitized dye*, it is shown that major shifts in the tool have had also profound effects in one of the main useful parameters of the DSSC (Litvin, 2011), its *energy efficiency*. The inclusion of Ruthenium salts in the sensitized dye in 1991. O'Regan & Grätzel (1991) brought a breakthrough with an energy efficiency about 10 %. Years after, again the shift of the sensitized dye i.e. the tool, (Kannan et al., 2012; Yella et al., 2011). The use of P-porphyrine as sensitized dye in 2012 brought a 12 % efficiency, and in 2013 the use of perovskite brought a new breakthrough reaching a 15 % efficiency (e.g. Upadhyaya et al., 2013).

The relevance of the tool and how it concentrates more research efforts than other components in the DSSCs is showed later in the present analysis. To measure this relevance, the rest of the components have been also analyzed. The present analysis started with the counter electrode due to its contribution in the overall efficiency of the DSSC (e.g. Li et al., 2011).

Figure 3 represents the trend of citation of two major counter electrode types after the analysis of 11.373 ISI WOS articles from 1991 to 2013, following the nine steps of the decision phases and the techmining process (e.g. Porter and Cunningham, 2005) to analyze the state of the art and trends of the components. Also, the aggregated values are shown.

The techmining technique has helped to identify the dominant elements in the literature as materials for the counter electrode. The techmining technique also helped to identify the 'What' (Cunningham, 2009). By exploring the trend in figure 3, it seems that platinum and carbon are most used as materials for the counter electrode. The use of different technologies for the fabrication of the counter electrode shows the systemic dimension of said component Li et al. (2011). The 'tool' in the subsystem 'counter electrode' is the layer of Pt in the case of a platinum counter electrode. According to the relevance of the

systems, the tool should be maintained, although the cost of platinum is not practical for large scale manufacturing, consequently, researchers have been simplifying the counter electrode progressing to the use of the less quantity possible even to the atomic scale, however maintaining it. The same can be said for carbon based counter electrodes, although the cost in this case is a less relevant issue (e.g. Yue et al., 2014).

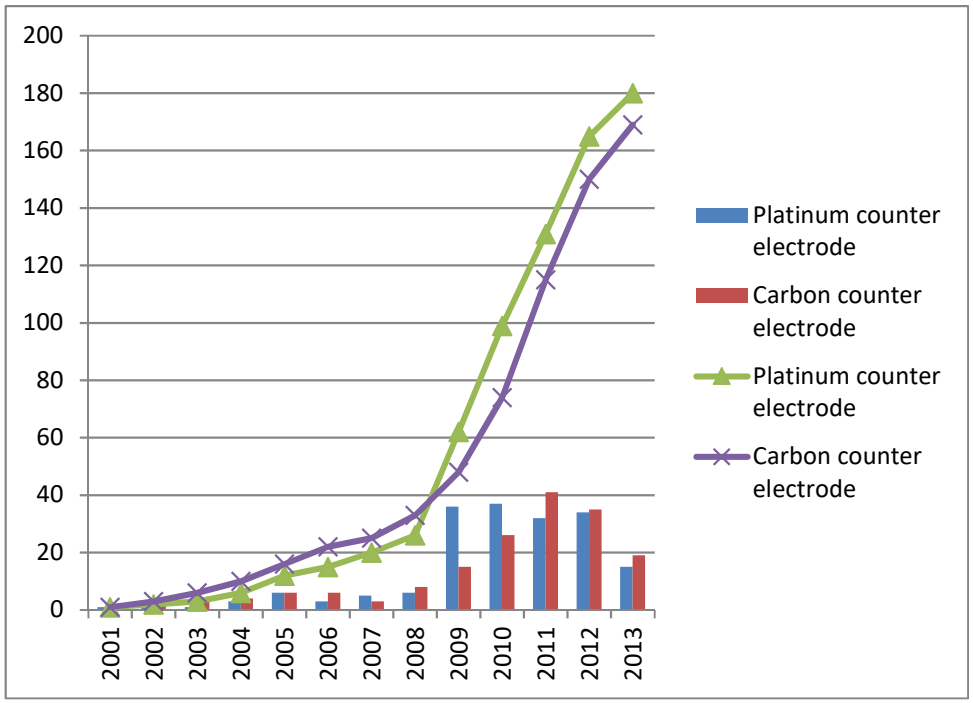

Figure 3. Pace of publication and cumulative values.

It is to note what can be a decreasing citation in time, of the counter electrode among all the 11,373 DSSC articles, as shown in figure 4. Comparatively to figure 5 which shows a more pronounced pace of publications citing activity on sensitized dye, it may explain certain concentration of activity in the 'tool' of the DSSC system which is more prone to bring relevant results among all components of the system. Any change in the dye may bring more relevant results than changes in other components. This will be also shown later with the analysis of the electrolyte.

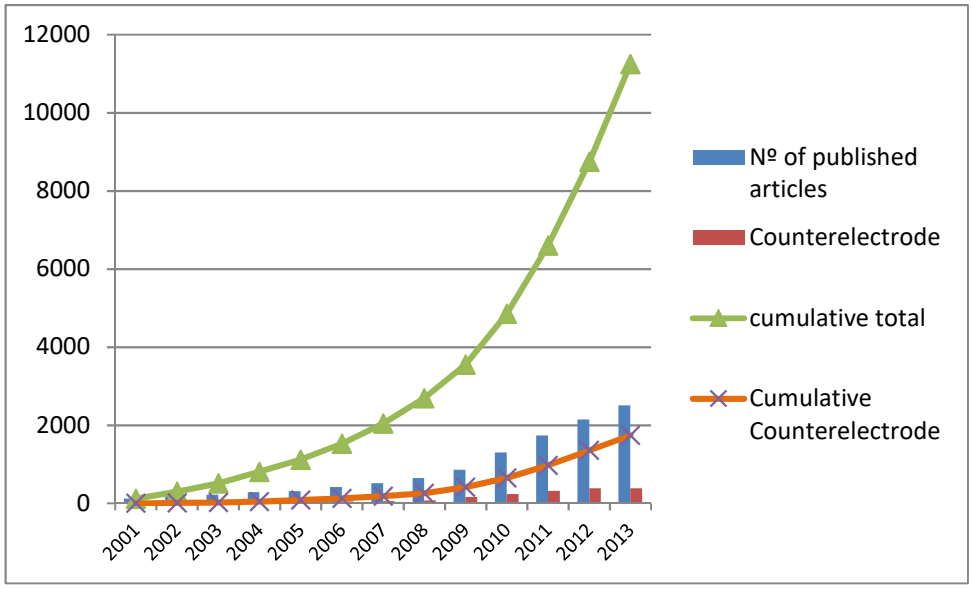

Figure 4. Pace of citation of counter electrode in the total number of articles about DSSC.

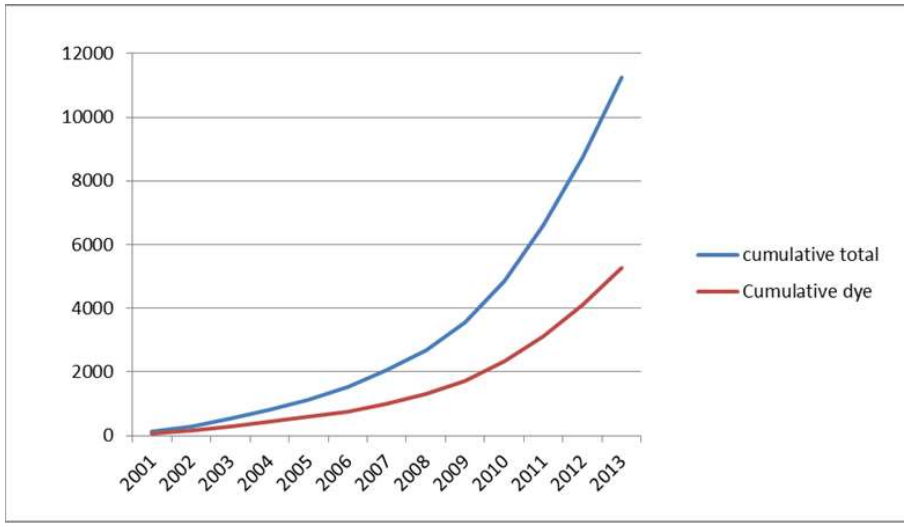

Figure 5. Cumulative citation of sensitized dyes.

This brings a key observation in which, knowing the systemic functional organization of the system helps to understand where the research efforts may concentrate in advance. This point should be further explored with other technologies and so the systemic view could prove worth to provide key insights for characterizing progress research activity and evolution potential.

By using the semantic TRIZ, by means of semantically analyzing records of full text patent documents with application dates from 1991 to 2013, the author started complementarily to explore the type of counter-electrodes, the relationship of its constituent sub-components and therefore started to explore the 'How' of such electrodes (e.g. Vicente-Gomila and Palop, 2013). A first extraction is shown in Table 1 as a way of example.

The Table 1 highlights the material and somehow the manufacturing procedure or the design configuration. For instance, entry number 68 whose applicant is *3GSolar Ltd*. details the architecture of the carbon counter electrode of nanocrystals bonded with titanium, or the architecture of the entry 75 of applicant *Inoue Teruhisa* from Japan, which covers several base materials bonded with a vapor deposited film of several conductive metal elements. These last examples show that citations only, at least in patents may lead to not accurate inferences, since patents tend to cover and to cite many materials and substrates to protect a broader field.

The combination of trends with the semantic contribution of methods or materials related to the counter electrodes may improve the view of what is really occurring in the development and evolution of the counter electrode component in the DSSC system.

Table 1. Extraction of counter electrode materials from 2009 patents (patents source micro-patent)

65	platinum counter electrode	As shown in the figure, the photosensitized electrode 1 according to the present invention is assembled with a **platinum counter electrode** 51 to form a solar cell device filled with an electrolyte 52 inside.	InN/InP/TiO2 photosensitized electrode	Most relevant	EP-1887592 B1, US-7622397 B2	**Institute of Nuclear Energy Research, Atomic Energy Council**(Lungtan,China
66	nickel counter electrode	There is no particular limitation to the kind of the counter electrode 43 as long as the counter electrode 43 ifformed by a conductive substrate. A conductive metal such as titanium, aluminum, and **nickel** can be cited as an **example of the counter electrode** 43. In the counter electrode 43, in order to promote the redox reaction of the electrolytic solution, a catalyst is provided in a surface contacting the electrolytic solution. Examples of the catalyst include platinum, graphite, and an organic polymer. The catalyst is provided on the counter electrode by platinum sputtering, a method of reducing a platinum colloid solution, graphite application, or organic polymer spin coating.	Dye Sensitized Solar Cell	Most relevant	US-20090000661 A1	**YOSHIMOTO, Naoki**(Hitachinaka, Japan
68	carbon counter-electrode	Each element includes a light facing anode comprising nanocrystalline titania, a **carbon counter-electrode** (cathode), which is a porous, catalytic, electrically conducting carbon-based structure bonded together using a titania binder, and separating the anode from the cathode is placed an intermediate…	PHOTOVOLTAIC DYE CELL HAVING AN IMPROVED COUNTER-ELECTRODE	Most relevant	WO-2009027977 A2	**3GSOLAR Ltd.** (Israel);
75	polymer film	Examples of **counter electrodes** which can be used include glass or a **polymer film** on which platinum, carbon, rhodium, ruthenium or the like are vapor-deposited, or conductive fine particles are applied.	Dye-Sensitized Solar Cell	Most relevant	US-20090242027 A1	**Inoue, Teruhisa**(Tokyo, Japan
77	thin Pt layer	The conductive layer and **thin Pt layer** are to be a **counter electrode** of the solar cell.	Dye-sensitized solar cell	Most relevant	US-20090199896 A1	**Oki Semiconductor Co. Ltd.** (Tokyo, Japan)

The counter electrode, as every part of the DSSC system, is a 'subsystem', a system itself, and therefore is constituted of parts or components. The functions of such components are also semantically extracted, therefore explored and interpreted. The results collected so far show that most of the materials and techniques of the counter electrode are also being developed in other industries such as the LCD or TFT screens.

Figure 6. Systems to which the component ITO precoated glass pertains.

Figure 6 shows that other technologies, as photo sensors or photolithography also use ITO precoated glass substrates as in the DSSC counter electrode. Some components seem to be 'horizontal', they may contribute to the DSSC research as well to other systems. It is of great interest to explore such 'horizontal' materials to see what are the possible trends or opportunities and if they can also be applicable to the DSSC technology.

Table 2 shows different applications of platinum counter electrode obtained by sputtering of a platinum thin layer, where it can be seen that different devices, other than DSSC, take advantage of such technique for fabricating a counter electrode.

Table 2. Different applications of platinum counter electrode obtained by sputtering of a platinum thin layer *(source patents from 1991 to 2013)*.

Pt sputtering electrode	
Application	**n° of occurrences**
electrode in fuel cell	59
counterelectrode in a potentionstat	37
electrode in light emitting device	23
Counter electrode in DSSC	21
Counter electrode in electric-neural interfaces	16
cathode in thin film sensor	12
Counter electrode in proteolytic electronic mediator	11
Counter electrode in transcriptional device	10
Capacitor electrode in flash Eeprom	9
electrode in PZT capacitor	7

Another result of the combination of techmining and semantic TRIZ derived from Tables 1 and 2 is the parallel trend of some components in the DSSC system and in other technologies: This parallel trend can pose questions such as who is 'driving' whom, *the hen or the egg*, and therefore may determine the outcome. In that sense, Yue et al. (2014) mention the use of polypirrole as highly used material in other technologies than DSSC, for instance in other electrical devices and detectors.

The systemic point of view helps to see, through the connecting functions of different elements, that the components of a system are connected also to other systems and so its identification may help to explore the trends of such 'other' systems. Furthermore, the systemic point of view helps also to see the whole picture and, referring again to figure 1, in the DSSC system, it may help to understand or recognize some of the current component problems. For instance, in the case of the electrolyte in Bella and Bongiovanny

(2013) and Rahman et al. (2014) there is a clear component conflict in the DSSC electrolyte. A good cross-linking by photoinduced polymerization seems to increase its stability and retain its gel like properties, however it hinders conductivity, whereas a less cross-linked electrolyte is less stable but offers a higher conductivity.

To explore this limiting effect, as well to better understand its advantages and disadvantages or the specificity of its development, the next component to be analyzed is the electrolyte in the DSSC. The electrolyte is responsible for transporting the ions from the counter electrode to the working electrode and vice versa. Figure 7 again shows the pace of citation in the research articles from 1991 to 2013 of the diverse types of electrolytes used. Figure 8 shows the comparison between the citation of all types of electrolyte in DSSC and the total published articles analyzed. Again, a decreasing pace of citation can be noted.

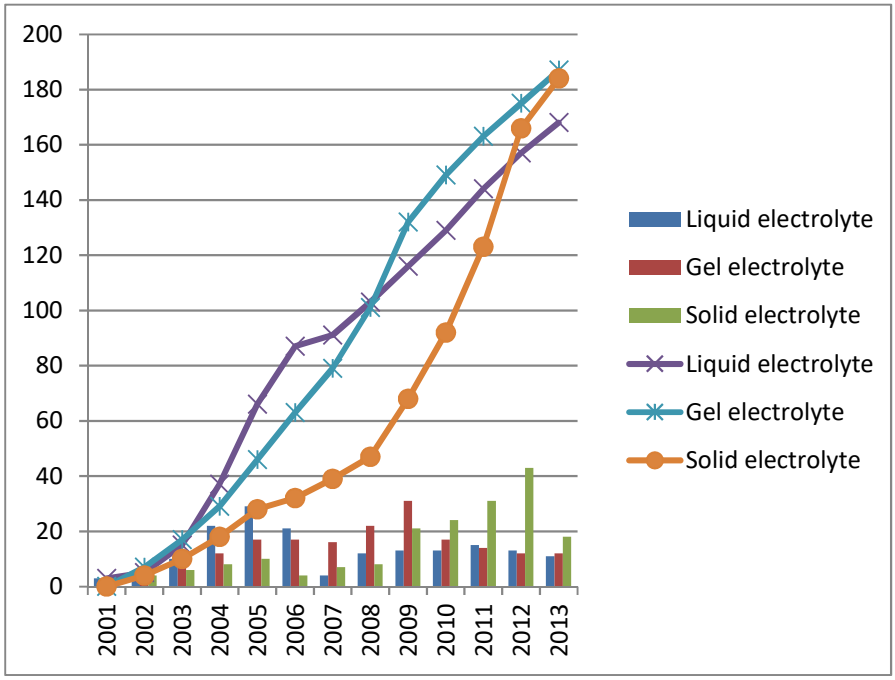

Figure 7. Citation of different electrolyte types and cumulative.

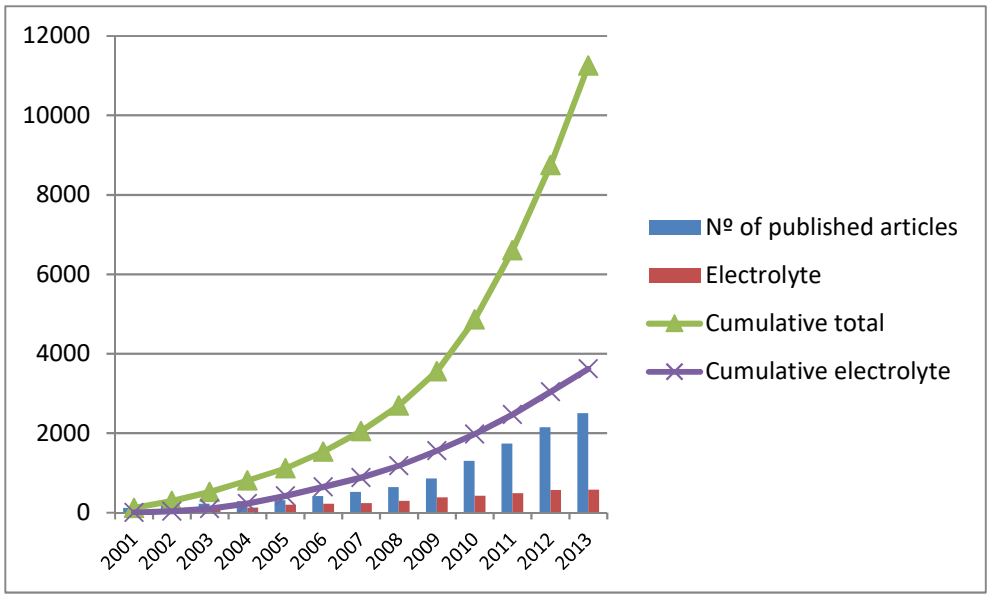

Figure 8. Comparative pace of electrolyte citations.

According to Rahman et al. (2014), liquid electrolytes are preferred against polymer electrolytes due to a better electron/ion mobility however they face several problems. Among the liquid electrolytes, room temperature ionic liquids RTIL's, do offer low volatility and better stability, however, they have a relevant drawback which is their relatively high viscosity. Again, it is interesting to check with the help of semantic TRIZ, the diverse ways of published solutions to lower the viscosity of RTIL's. Table 3 offers a list of alternatives to lower the viscosity coupled with the technology to which it is associated. It shows that the problem is not restricted to DSSC's system, but other systems using electrolytes as some batteries. As discussed before, the components of the DSSC system are not exclusive and its development should also be analyzed in other systems to see which system is driving the progress and which other systems are benefiting from that progress.

Table 3. List of some alternatives to reduce the viscosity of RTIL's.

Solution	System involved	Reference
Dry toluene, **xylene**, **decalin** or the like **containing a nanoscale particulate polytetrafluoroethylene powde**r suspended therein by ultrasonication is added to reduce the viscosity of the RTIL	silicon nanoparticle manufacturing	US 20140227548 A1
Short ether groups reduced the viscosities and melting points of RTILs	lithium ion battery	Organosilicon functionalized quaternary ammonium ionic liquids as electrolytes for lithium-ion batteries; Ionics September 2014, Volume 20, Issue 9, pp 1207-1215
Addition of Acetonitrile exponentially increases diffusion and decreases viscosity of the RTIL/ACN mixtures	electrolytes	Acetonitrile boosts conductivity of imidazolium ionic liquids J Phys Chem B. 2012 Jul 5;116[26]:7719-27. doi: 10.1021/jp3034825. Epub 2012 Jun 21
reduction of the concentration of LiTFSI in P13TFSI to improve the Li+ conductivity of the electrolyte and because of the decreased viscosity of the electrolyte	lithium-sulfur batteries	Effect of cations in ionic liquids on the electrochemical performance of lithium-sulfur batteries Sci China Chem November [2014] Vol.57 No.11
In the case where R1 to R5 in the general formula [G1] are an alkyl group having 1 to 20 carbon atoms, **carbon atoms having small carbon number** [for example, 1 to 4 carbon atoms] is used because the viscosity of the synthesized room-temperature ionic liquid can be reduced; which is preferable for a power storage device.	power storage device	US 20140342245 A1

Returning to the conflict seen in Altshuller (1984) the need for a gel like electrolyte for increased stability, but decreased conductivity against a liquid like electrolyte for an increased conductivity, but decreased stability speaks want in TRIZ methodology is called a physical contradiction which offer several paths to tackle this problem. Researchers have tried to overcome this problem by adding plasticizers (e.g. Bella and Bongiovanny, 2013) therefore adding elements which may increase conductivity but may present other drawbacks. Instead, separation is one of the strategies to overcome such problems and in the case of cross-linked electrolyte, it could mean separation in space which could be translated to a cross-linked area where it is needed, i. e. At the edges of the DSSC device or at the contact with the electrodes, whereas liquid in the inner part helping to conduct the ions as needed.

Chapter 5
Extended abstracts of the articles

5.1. The first article: '*Combining techmining and semantic TRIZ for a faster and better technology analysis: a case in energy storage systems*'

The first article tries to demonstrate through the analysis of the lithium batteries, the advantages of combining the approach of techmining and semantic TRIZ. The identification of trends and weak signals and of functions and causes and effects, allow a better understanding of the trends and evolution of technologies with less effort involved. In such research, the authors analyzed a sample of the scientific and technological literature around the energy storage system for electric vehicles and more concretely around the materials on which such technologies are based. The techmining technique had helped to detect existing and emerging collaborations. The semantic TRIZ technique had helped to understand the relationships of the components of the technology as well as of this ecosystem (Adner and Kapoor, 2016).

The first article also highlights the complementarity and interrelation of the techmining approach and the semantic TRIZ approach to explore the trend of a technology in a more holistic way, see Table 4.

Table 4. Capabilities of techmining and semantic-triz.

Capabilities of semantic-triz	Capabilities of Techmining
Identify functional relationships as problem - solution	Identify trends for any term or substantive phrase
Identify causes and effects,	The cross relation of different technology related variables such as domain, affiliation, keywords, multiterms of abstracts and titles, etc.
Identification of functions and actions relating technologies or components of a technology or of a material	Visualization maps and network maps
Direct strategy of search	Co-occurrence matrices
Advantages and disadvantages of a technology, a component or an ingredient.	Auto-correlation of maps and matrices
Answers the *How*, the *Why,* the *systemic components*	Answers the *Who*, the *Where*, the *When* and the *What*

The authors propose a different approach to analyze specialized technologies. Such approach was based in understanding the interest among researchers and their prospective view by analyzing more cited and more recent reviews and by collecting their opinions. This may reduce or even eliminate the need of many 'scientometric' researchers, to count on domain experts to progress in their projects (Cozzens et al., 2005; Cozzens et al., 2010).

A first result of this research was to identify a disrupting material used as cathodes in the lithium storage systems as the LiFePO4 against materials as lithium-magnesium or lithium-cobalt, two well-known materials also being of interest in the research trend.

Another interesting trend was the increasing presence of doping among cathode materials, in particular the use of nanostructures as doping in the currently used technologies. In such case the identification of clear trends, complemented with the modes of usage of such nanostructures, helped to understand and to interpret the fundamentals of such increasing presence.

Another interesting result was the identification of collaborations based on their research contributions of the main actors in the energy storage technologies. The addition of a TRIZ based systemic functional subject-action-object map, revealed the limiting func-

tions and by that time the existing bottlenecks. The techmining approach helped to measure the amount of research in such limiting functions, and the pace of the future lithium-air cathodes.

With the help of the combined approaches, non-specialists can interpret the result of analyzing thousands of research papers therefore have a larger view in assessing an emerging technology. This first article was an attempt to explore the synergies of both techniques combined.

5.2. The second article: *'The contribution of syntactic-semantic approach to the search for complementary literatures for scientific or technical discovery'*

The second article tries to demonstrate the capacity and the possibilities of the semantic TRIZ concept complementing the state of the art practices of techmining to discovery new knowledge through the search of complementary literatures. This search was started by MD. Swanson in his seminal paper (Swanson and Smallheiser, 1997). To explore this contribution the author made a research into the existing techniques and methods for literature based discovery, their achievements and their limitations. The logic links and relations among terms in the semantic TRIZ technique could offer key advantages as well as a structured step by step method to literature based discovery. To further explore such contribution, two different problems were analyzed: the hearing and balance problem known as Ménière's disease and to some of the existing problems with the then future lithium-air batteries explored in the first article.

Among the different research methods for literature discovery, mainly *the closed discovery approach* where the research starts with one problem and its solution and then tries to find reasonable connections between them and a second approach known as the *open discovery approach*, where the research starts with one problem and arrives to a solution from disparate literatures. This second article was based on exploring the possibilities of semantic TRIZ in the open discovery approach.

The contribution of this second article was to find links with human like logic sense. The identification of semantic logic links and, true sense cause-effect relationships, builds up a structured path to discover new knowledge connections in disparate literatures: It implies also less need of expert involvement at every step of the traditional LBD method.

To demonstrate and to explore the capabilities of using semantic TRIZ as support for literature based discovery (LBD) one of the domains analyzed was the Ménière's disease. For that, the author mined a sample of several sets of the Elsevier's Science Direct database of full articles. Some of the original possible connections were:

Insufficiency of vitamin A → (effects) → (middle ear) Eustachian tube blockage → (causing) Ménière's disease

Blood flow → (effects) → endolymphatic duct blockage → (causing) Ménière's disease

By that time there was no direct connection in the literature between vitamin A and Ménière's disease showing the benefit of a logic structured approach to finding relations among disparate literature. These results may have profound impacts on how the National Patent Offices define the degree of inventiveness or the 'state of the art'.

A second exploration in the sense of the latter exploration of solutions in the 'state of the art' or the 'degree of inventiveness' was done with one of the limitations of the lithium-air research efforts as was the increase of material porosity at a nanostructure level of cathodes.

Addition of metal oxide → (effect) macro and microporosity → activated carbon → lithium-air cathode.

The results of both cases demonstrated in a first attempt that LBD can be enhanced, can be better structured and with less uncertainty, by adding the semantic TRIZ approach.

More research and more sources can finally consolidate such approach of semantic TRIZ and natural language processing to the work of techmining used for LBD, and could be used for any academic research work.

5.3. The third article: '*O acesso transversal ao conhecimento no processo da pesquisa médica: diagnósticos e biomarcadores no cãncer da próstata'.*

This third article, presented at International Congress Medinfor III ISSN 2358-3266, focus on the combination of the two approaches and arrives at the conclusion that only by combining the two methods a more comprehensive analysis of a technology can be achieved. In today's global landscape, innovation is crucial to the competitiveness of organizations. Thus, also medical centers should be aware of advances in modern technologies for the treatment of diseases. However, widespread climate of lack of private and government funding, coupled with the increasing explosion of medical scientific research, revealed the complexity in identifying and adopting effective strategies in managing innovation. This paper presents an approach based on the type "computational linguistics" tools and CAI (computer-aided innovation). It is shown that, through a combined approach plus the use of the computer programs of techmining as VantagePoint, and semantic Triz ones as GoldFire, the National Institute of Oncology Colombia could identify detection systems and, the most promising groups of participating researchers and their partnerships related to the diagnosis and prognosis of prostate cancer research. With less involvement of specialists and by proposing side related methods not very familiar to some specialists.

For analyzing the different biomarkers as elements for diagnosing the prostate cancer, the authors mined the databases of Medline Pubmed, Elsevier Science Direct, Springer

Verlag, arxiv.org, etc. Also, an international patent database from micropatent was mined. As an example, only from PubMed-Medline, more than 79.704 records were retrieved, mined and analyzed. The mining of terms extracted from the abstracts of such records reached more than 1.276.818 different terms. The figure 9 shows a trend of different biomarkers as with higher research activity.

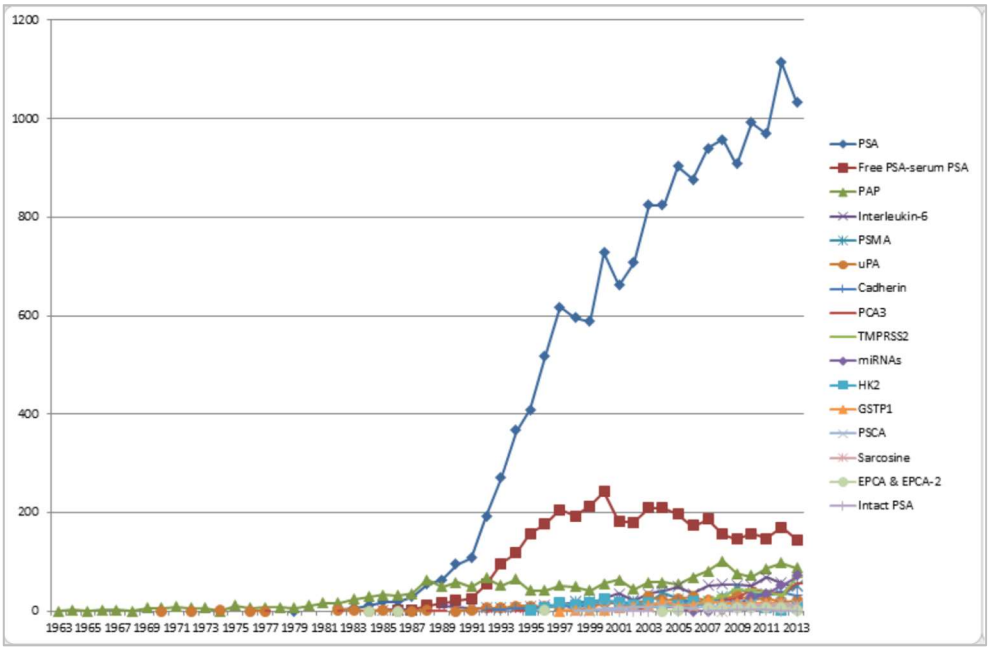

Figure 9. Trends of biomarkers.

However, such trend in techmining was complemented with a search based on diagnosis methods, without focusing in any biomarker or keyword, to be able to detect any new perspective which could arise. One of the new key results was the advance in imaging and moreover in software for analyzing the images. These imaging methods were the most cited for diagnosing prostate cancer, protected through patents.

These results show how complementing techmining with semantic TRIZ may help see trends but also to broaden the focus to unexpected areas. This again, allows to repeat the process to see the trends in the new areas.

The Table 5 shows a list of such methods.

Table 5. Methods for diagnosing prostate cancer.

Detection of Cancer Methods	Citation Example	No. of occurrences
Immunological imaging method	In addition, immunological imaging methods capable of detecting prostate cancer and other cancers expressing 213P1F11 are also provided by the invention, including but not limited to radioscintigraphic imaging methods using labeled 213P1F11 antibodies. U.S. Granted Patents**:** Nucleic acid and corresponding protein entitled 213P1F11 useful in treatment and detection of cancer.	462
In vitro method	the invention provides an *in vitro* method of (a) diagnosing prostatic intraepithelial neoplasia (PIN) or prostate cancer (PRC) or a predisposition to PIN or PRC in a patient, (b) monitoring a course of treatment for PIN or PRC in a patient, or (c) for prognosing PIN or PRC in a patient	62
Utilization of STEAP polynucleotide	to observe the presence and/or the level of PSA mRNAs in methods of monitoring PSA over expression or the metastasis of prostate cancers, the STEAP-1 polynucleotides described here in can be utilized in the same way to detectSTEAP-1 over expression or the metastasis of prostate and other cancers expressing this gene.	30
measurement of expression of mRNA in tissue sample	In some preferred embodiments, detection of prostate cancer markers (e.g., including but not limited to, those disclosed herein) is detected by measuring the expression of corresponding mRNA in a tissue sample (e.g., prostate tissue). mRNA expression may be measured by...	23
comprising of probe by detection system	For example, a detection system can comprise one or more probes to detect one or more prostate cancer specific biomarkers, such as ACSL3-ETV1, C150RF21- ETV1, FLJ35294-ETV1, HERV-ETV1, TMPRSS2-ERG, TMPRSS2-ETV1/4/5, TMPRSS2-ETV4/5, SLC5A3- ERG, SLC5A3-ETV1, SLC5A3-ETV5...	22
prognosing of prostate cancer	In another aspect, the present invention provides: in vitro methods of diagnosing and/or prognosing prostate cancer, PIN or a predisposition to developing same in a patient.	22
utilization of 161P2F10B polynucleotide	...1190 (2000)) to observe the presence and/or the level of PSA mRNAs in methods of monitoring PSA over expression or the metastasis of prostate cancers, the 161P2F10B polynucleotides described herein can be utilized in the same way to detect 161P2F10B over expression or the...	21

5.4. The fourth article: "*Discovering shifts in competitive strategies in probiotics, accelerated with techmining*".

Scientometrics

The fourth article is an exploration of the advantages of techmining to detect changes in the strategic intent of competing companies by means of analyzing the claims of the patent portfolio of every competing company. By using a combined techmining approach and the semantic TRIZ approach, it is possible to understand key insights in the strategy of companies in the probiotics market for livestock. Companies in such field of science claim protection in key probiotic ingredients and therefore offer clues about their technological and strategic intention.

The paper tried to overcome the limitations of using keywords, by focusing on one critical field of the patent document: the claims. It is in the claims where applicants try to protect their technology strategy. Besides, the paper focused on the earliest patent of the INPADOC patent family, which had claim text in English. It is relevant to select only one family member in order to avoid repeated count of terms in the analysis. The research profiling of claims implied analyzing the keywords mentioned in the claims. Identifying the key terms in the claims and plotting such terms against time allowed to understand the trend in key elements, probiotics and prebiotics in the paper. The monitoring of such strategy for every company in timeline, gives a good perspective for competitors to detect shifts and special movements of the target company.

Figure 10 shows the trend in citation of the key ingredients cited in the claims of the patents and so the key ingredients to be protected by the company Nestec. It clearly shows in a graphical way how they were abandoning little by little the oligosaccharides and started for other prebiotics.

Table 6 further explores the applications of the new prebiotics to better understand the strategic technological intent of the company.

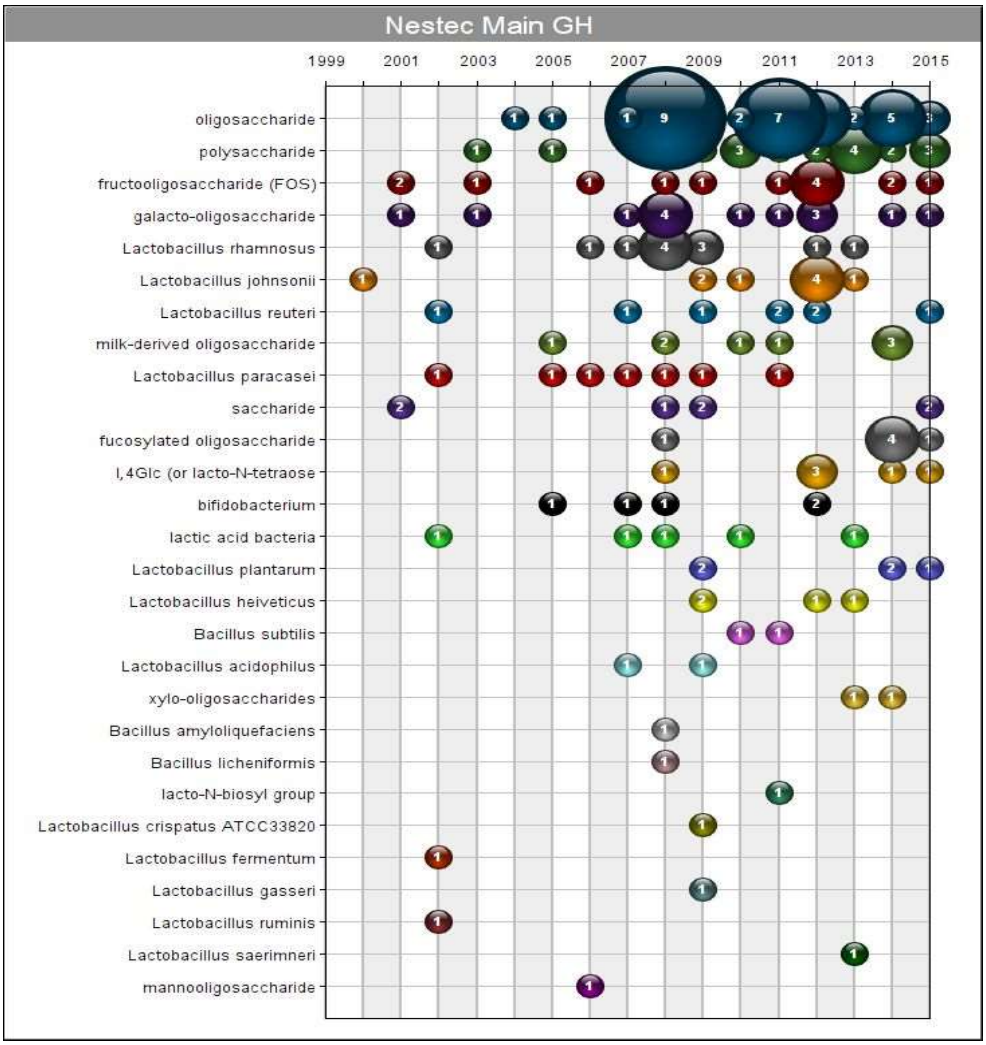

Figure 10. A bubble map with trends about health agent terms in claims of one of the companies analyzed in the paper.

Table 6. The table shows some key applications of *fucosylated oligosaccharid*e as a health agent extracted from the set of patents.

Fucosylated oligosaccharide uses or applications	
As a competitor for pathogens	(2)
Inhibition of stable toxin of Escherichia coli	(2)
As prevention of influenza infection	(1)
For combating multiresistant bacteria	(1)
As health promoter	(1)

The process described in the paper is summarized as follows:

1. A search in in a patent database brought 1993 patent families
2. NLP processing and extraction of claims terms
3. Removing common, noisy terms via fuzzy matching and cluster suite script, both in VP and manual touch up. Using the thesaurus grouping
4. Extracting terms with a factors map and further selecting with the help of experts from IRTA
5. Establishing a relationship of subjects and objects and cross correlating them with the help of the co-occurrence matrix
6. Going further the comparison of terms but also adding the dynamics of such terms against its distribution in time to see the dynamics of key elements in the claims and, to see the shifts and changes in time
7. Take advantage of semantic processing to add meaning about the uses and properties of any of the components in the claims

Chapter 6
Can the combination of techmining and semantic TRIZ bring some advantage in technology analysis? A case in energy storage systems

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Combining techmining and semantic-TRIZ for a faster and better technology analysis: a case in energy storage systems

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Abstract

Understanding and anticipating the evolution of technologies is an increasingly complex task attributable to the interdisciplinarity of the technology and the explosion of information about the research and patent activity. By combining the capabilities of techmining in identifying and in highlighting trends, weak signals, with those of semantic-TRIZ (*Teoriya Resheniya Izobreatatelskikh Zadatch* – Theory of Inventive Problem Solving)

in identifying the functions, its causes and effects, a better understanding of the trends may be obtained in a shorter time.

An interesting trend in the use of graphene in cathode materials, as well as its applications, mainly to enhance the conductivity and the discharge and recharge of the Li–air battery, has been quickly assessed because of the combined techniques. Another two cases, the increased presence of nanostructures in cathodes and the emergence of LIFePO4 in the lithium–ion batteries have been also analyzed in a brief time. The results may predict the good possibilities of the combination of these two evolving techniques.

Keywords: techmining; semantic-TRIZ; lithium–air battery; technology analysis.

Introduction

There have been many attempts to introduce electric vehicles into the market place since Krieger in 1897, later by the General Motors (GM) Impact in 1990 (Blosseville 2010), but massive market penetration of the hybrid vehicle was started by the push of Toyota Prius. In addition, the population's increasing awareness of global climate change, in addition to escalating oil prices, have made almost irreversible the progress of the electric vehicle (EV) including all its components and related elements. Although the source of energy most currently used for such hybrid vehicles has been that of the metal hydride variety, the 2012 Prius is using the Li–ion type and it is already used in vehicles such as the Tesla Roadster, the Nissan Leaf and the current electric vehicles from Renault, to name but a few.

One of the significant limitations restraining the progress and development of the electric vehicle (EV) is its autonomy. The increase in travelling distance without recharging depends primarily on energy storage systems and the total weight of the EV. The current energy storage systems or batteries for the EVs are limited in performance, cyclability, energy density and range; at the same time, an EV's batteries are heavy. Batteries are the key element of the extra cost of an EV (Williams 2011; Amirault et al. 2009). Reasonably, there is a research effort in alternative technologies on which the next energy storage systems may be based.

It is therefore interesting for the EVs' value chain stakeholders, researchers, component suppliers, designers, investors and manufacturers, to distinguish between different alternatives and what materials and technologies can be adopted, which can become dominant or which may have a higher yield potential. Even for tier 1 suppliers of the automobile industry, it is critical to choose among different approaches to shape their strategies and to adopt less risky positions in mid-term.

However, knowing about key technologies and their innovation potential is difficult for non-experts or industry staff because it increasingly depends on critical new technology

and science-based knowledge access (Porter and Cunningham 2005). Simultaneously, such new knowledge is increasingly multidisciplinary and distributed across different fields as most of the technology fields are advancing not only in components but also in materials and in nature and properties of such materials. The increasing knowledge about material science opens paths to further advance and progress in every technology (Adams and Pendlebury 2011; Bensaude- Vincent 2004). Moreover, with the information explosion, it is necessary to dig across large and varied volumes of scientific and technology production, which contrast with the reduced time available for comprehension and decision making (Hemp 2009). Therefore, it is increasingly strategic, but more difficult to identify potentially emerging technologies in advance.

The main purpose of the present research study is to introduce the advantages of combining two FTA (future technology assessment) techniques, semantic-TRIZ (*Teoriya Resheniya Izobreatatelskikh Zadatch* – Theory of Inventive Problem Solving) and techmining, to achieve a better and faster understanding of a technology analysis. In order to demonstrate the potential advantages of such combinations, the authors have applied both techniques with the aid of experts' analysis to the current research and technology activity about the electric vehicle and, especially, to the electrode materials of its energy storage system. Prior results of this approach were presented in the 13th EAEC European Automotive Congress (Vicente-Gomila and Palop Marro 2011). The present attempt to explore the combined techniques will focus on the lithium battery system and particularly on the electrodes and their materials owing to their relevance in lithium-based batteries (Ng, McLean, and Hibbard, 2006).

Theoretical background

The identification of emerging technologies introduces more variables than just accessing large volumes of research and patent literature. It usually involves the participation of industry experts to assess any conclusions (Cozzens et al. 2010). However, the increasing progress of the information technology applied to meaning and knowledge extraction, present several advantages to the information vs time conflict, and it may help to reduce the dependence on industry experts to draw some conclusions.

To date, mainly statistical and prospective methods (Martino 2003) have been used to evaluate or forecast the evolution of technologies. More recently, techmining has joined the understanding of technology dynamics with the statistical capability of extracting text terms, their occurrence and other statistical interactions to respond to relevant management of technology questions (Porter and Newman 2011). The progressive advance of semantics (Feldman et al. 2003; Verbitsky 2004; Hai and Hanhua 2008) to analyze texts is allowing us to extract meaning or logic relationships from the published research activity. Techmining answers questions such as *what*, *where*, *when* and *who*, and semantic-TRIZ can answer questions about *why* and *how.*

The authors have explored the techniques of techmining and semantic-TRIZ and their combination, and some results *and limits* are shown in the present paper. To explore these two techniques, supported by experts 'assessment in the form of analyzing latest research reviews, the authors have analyzed and mined a sample of the scientific literature around the energy storage system for electric vehicles and particularly around the materials which are shaping such technology (Song et al. 2011). The techmining technique helped to uncover existing and nascent collaborations as well as outstanding increments in various materials and elements, structures and nanostructures related to lithium batteries. The semantic-TRIZ technique complemented the techmining by helping to understand the current uses of such technologies, as well as the functional relationship of their components and the functional relationship to higher structures, i.e. helping to understand the systemic relationships. This latter approach is known as *mereology*. Such components as well as their functionalities or uses of existing and new technologies have been also explored with the systemic-TRIZ approach to technological systems.

Techmining (Porter and Cunningham 2005) is a discipline involved in applying information tools to count, interrelate and to analyze science and technology information to help to understand changing and emerging technologies. Search Technologies' Vantage-Point is a techmining tool which helps to analyze, validate and qualify a large amount of data. It can extract and elucidate trends, relationships, hidden research networks and weak signals from a vast database of scientific articles. Complementary to the analysis of co-words, techmining involves the use of technology measures and innovation indicators to help understand the dynamics of the obtained results and its importance to the subject matter analyzed.

TRIZ (Altshuller 1996) is the Russian acronym for 'Theory of Inventive Problem Solving', heuristically derived from inventive and technology patterns extracted from hundreds of thousands of patent documents. TRIZ helps to understand the technology as an interrelated system and its possible architectural evolution. Its knowledge helps in this paper to interpret some of the latest advances in lithium-based storage systems, complementing the usage of techmining analysis techniques.

Semantic-TRIZ (Verbitsky 2004) is based on extending the view of systemic functional relationships identified in TRIZ among the components, energies and information relationship of a device or a technology, with the help of linguistics. Semantic-TRIZ links syntactically the problem with a solution in a research document or a patent. Implemented in the IHS's Goldfire software tool, such technology uses linguistic techniques such as mereology, anaphora resolution, cause– effect analysis and question-answering to link the functions of a technology, its components and their relationships. It is therefore able to link the knowledge of the user with different – even new – knowledge extracted from documents.

Differently from the general approach to techmining alone, the method of combining the techmining technique with the semantic-TRIZ technique, starts by understanding the current interest and prospective view of an expert, by analyzing review papers and by

collecting some of his or her opinions. In the documented techmining approach alone (Cozzens et al. 2005), the work starts by search and data mining of basic topical terms based on the 'problem' words and there then follows a download of a first set. The next step after reading some titles and abstracts is to refine the initial search, examining the keywords obtained and then, starting to plot trends, cross institution keywords, and different measures and innovation indicators to understand activity patterns.

As Cozzens recognizes, there is a need for a domain expert to assess whether a trend is an emerging technology or not and perhaps a need to establish a monitoring activity to see the evolution of such technology (Cozzens et al. 2010).

Wang, Chang, and Kao (2010) propose to combine tech analysis with a variation of the laws of system evolution based on the knowledge of TRIZ. Such an approach tries to interpret possible evolution directions as potential guides for R&D. More interesting is the contribution of Choi et al. (2011) building a network of subject–action–object sentences and then analyzing the relevance of different topics by applying the theory of networks. Such networks can be difficult to interpret for industry staff.

Methodology used

The authors of the present paper propose an approach based on combining the predominantly quantitative analysis of techmining plus the syntactic analysis of semantic-TRIZ, plus a qualitative expert assessment. The experts' assessment has been indirectly used at the beginning by integrating several of the most up-to-date review papers about the topic to identify main research areas, existing limitations and future areas of research (Rockett et al. 2011). The combined approach is complemented by contacting several field experts. From there, and with the TRIZ systemic scope, a systemic model of the technology with its functionalities is built and then, by identifying the trends with techmining of such terms and its functionality, some conclusions can be derived. As with the normal approach, the involvement of experts does help to realize the potential impact.

Moreover, with the syntactic relationship even the expert of the current domain can discover new answers from different industries, triggering paths for new directions or new possible exploration in an interesting time–performance ratio. All this can help to cast different technology scenarios to reduce uncertainty in decision taking (Bryan and Farrell 2009).

Table 7 shows several capabilities and complementarities between techmining and semantic- TRIZ.

Table 7. Some key capabilities of techmining and semantic TRIZ.

Some of the capabilities of semantic-TRIZ	Some of the capabilties of Tech-mining
Answer to a key question in technology assessment: How	Answer to key questions in technology assessment: What, Who, Where/When (Porter and Cunningham 2005)
Identify syntactic relations as functional relationships, assuming them as problem – solution	Identify trends for any term or substantive phrase
Identify causes and effects	Cross relation of different technology related variables such as domain, affiliation, keywords, terms and multiterms of abstracts and titles, etc.
Identification of functions and actions relating technologies or components of a technology or of a material. Relationship with other entities outside a technology	Visualisation maps and network maps Auto-correlation of maps and matrices relating materials within a technology or authors or affiliations related within a subject
Identification of conflicts, contradictions or limitations	Co-occurrence, cross correlation and factormatrices

Several combinations of both techniques can take several procedures. One is to start with the techmining technique to identify emerging and prevailing technologies. Afterwards, the semantic-TRIZ technique is used to dig into said technologies, to understand better the 'whys' and 'hows'.

This combination is the most used in this paper.

Another combination starts with a system analysis, which helps to determine the systemic relevance of current research limitations and bottlenecks or deficiencies of the system. Immediately or in parallel, techmining confirms the trend of current research efforts on such bottlenecks or limitations and their authors or leading experts. Semantic-TRIZ can also identify existing solutions either in the field or from other disciplines to overcome such limitations. The results also show this approach. To test the combination of the two techniques, a techmining exercise was developed following the nine steps of the decision phases and the techmining process (Porter and Cunningham 2005) to analyze the state of the art and trends of the most used electrode and electrolyte materials in the energy storage systems of the electric vehicles (Xu et al. 2009). To define the search strategies, the authors have considered using some previous bibliometric work with the same topics, as in Lin, Zhou, and Xuhui (2011).

One source of data has been used: Thomson Reuters' ISI Web of Science database, or ISIWOS, for the academic research articles. It is sufficient for the purpose of demonstrating the advantages of the combined approach. Further research work with the same methodological approach as the present work could be done only with patents or by combining patents and articles. With the inclusion of patents, it is foreseeable that more literature on uses and applications will be retrieved, as previously it has been only using research articles. The authors are aware that their conclusions can be only partial as the universe of the present work is only in the research arena, prior enough to the market.

The search strategy used as an example to explore the combined techniques was, at 28 February 2012:

TS=(((lithium SAME (air OR oxygen)) OR (Li/air OR Li/oxygen OR Li–air OR Li–oxygen)) AND (batter∗ OR electrolyte OR cathode OR anode OR EV vehicle∗ OR Electric vehicle∗)) NOT TS=(photon∗), with lemmatization on and limited to SCI-EXPANDED, SSCI,A&HCI, CPCI-S, CPCI-SSH; in all text fields; Timespan=All Years (2501 results). The same query strategy and the same source was used to explore Li–ion, Li–sulphur, LiCoO2, LiMn2O4, LiFePO4. For the last three materials, the queries are as follows:

(search in all text fields): (1) TS=((lithium cobalt oxide OR LiCoO2*)* AND (battery OR electrolyte OR cathode OR anode OR ion OR EV vehicle∗ OR Electric vehicle∗)) (2920 results)

(2) TS=((LiMn2O4*)*AND (battery OR electrolyte OR cathode OR anode OR ion OR EV vehicle∗ OR Electric vehicle∗)) (2313 results)

(3) TS=((lithium iron phosphate OR LiFePO4*)* AND (battery OR electrolyte OR cathode OR anode OR ion OR EV vehicle∗ (1632 results)

These three results were combined inside ISIWOS advanced search and the combined result was 6337 records at 29 February 2012.

The software tool VantagePoint from Search Technology Inc., accelerated the analysis of the articles' data records. Table 8 shows the number of records extracted. Subsequently the same raw data records were also processed with the software tool Goldfire from Invention Machine to extract the semantic-TRIZ functionalities, applications or limitations.

Table 8. Details of the search strategy and number of records extracted.

Terms restricted to the EV scope of research	ISI WoS number of articles retrieved
Li–ion	778
Li–S	689
Li–air	2501
$LiCoO_2$	2920
$LiMn_2O_4$	2313
$LiFePO_4$	1632

Notes: Timespan=All Years. Databases=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH. Lemmatisation=On. Fields searched: all text fields. The article results of the three materials related with the cathodes $LiCoO_2$, $LiMn_2O_4$ and $LiFePO_4$ were combined inside ISI WoS into a single 6337-article record set and downloaded to start the analysis.

In order to understand the share quotes of research at nanoscale in Li–air, the authors have taken keyword plus to define the scope and nanostructures in Figure 11, in this sense it is relevant to report that 8% of the 2501 records of Li–air arrived without keywords plus, and are not covered in the graph. This may explain some minor differences present in Figure 12.

Results

Within the Li–ion technology and with the techmining technique, different trends and collaborations have been identified, which will be discussed in the next few pages. A first trend relates to the current research activity among different materials for the cathode of Li–ion batteries in order to increase its performance in electric vehicles.

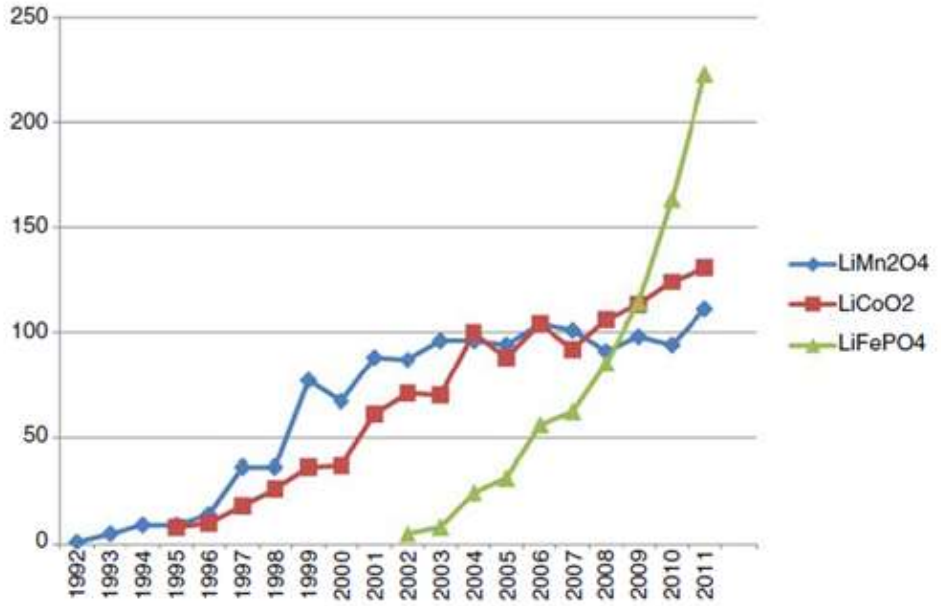


Figure 11. Trends in cathode materials for Li-ion (number articles per year).

As Figure 11 shows, the most-used materials currently in industrial use (Song et al. 2011) are the lithium cobalt oxide (LiCoO2*)*, lithium manganese oxide spinel (LiMn2O4*)* and lithium iron phosphate (LiFePO4*)*. To obtain such trends, first the authors removed duplicates among the list of articles and secondly grouped the related terms using Vantagepoint. The criteria for the groups were generated using the field ISIWOS Keyword Plus, that, in the opinion of the authors, has less risk of bias than the abstract terms or those from other fields. Especially when a research article mentions different materials or technologies, those mentioned in Keyword plus have been chosen for grouping or classification.

Lithium cobalt oxide (LiCoO2*)* has been historically the most used lithium–ion technology (Amirault et al. 2009) and, therefore, it has been supported by extensive research as well as for the manganese cathode. It is remarkable how the most recent material, LiFePO4, based in the olivine structure phosphate, has emerged as an almost prevailing technology displacing the other two in the research effort.

Although commercially, the three cathode materials coexist and are already being manufactured and supplied by several producers, the intensive prevailing research effort for LiFePO4 could be explained by its capability of being improved by doping, a method used for improving the performance of existing cathode materials (Fergus 2010) as well with nanostructured materials (Song et al. 2011).

LiCoO2 and LiMn2O4 can also be improved by doping; however, there are a higher number of possibilities with the LiFePO4. As nanostructures are being researched by using the three materials, it can explain why all three are ongoing in numbers of papers.

By analyzing semantically and syntactically the same records (mainly text fields: titles + abstracts), Table 9 shows a list of advantages of each of the three materials to help to understand the reason for the emergence of the LiFePO4 trend. Note that the cited initial discharge capacity is higher for the LiFePO4 (Damen et al. 2010). Also from the advantages of the three materials it can be seen that most of the good properties of LiCoO2 are either doped or are part of other material or as a coating, whereas for the LiFePO4, such properties seem to be a good material in itself. LiMn2O4 also shows some advantages by itself. Although these advantages are not conclusive, they can give even the non-expert an initial clue to the reason for the increased interest shown by the dynamics of publications in LiFePO4 disclosed by techmining and shown in Figure 11. If the same articles were in full text, more clear advantages or limitations could be extracted by semantic-TRIZ analysis.

Table 9. Advantages of LiFePO4, LiMn2O4 and LiCoO2.

Advantages LiFePO4
Solution name: Lithium-ion intercalation behaviour of LiFePO4 in aqueous and nonaqueous electrolyte solutions 2008
LiFePO4 showed a much **better rate capability in** the **Li2SO4 aqueous electrolyte** than in the 1 M LiFP6-PC nonaqueous electrolyte
Solution name: Synthesis of LiFePO4 cathode material by microwave processing 2003
The **LiFePO4** obtained has a high electrochemical capacity and **good cycle ability**.
Solution name: Lithiation Behavior of LiFePO4 in saturated lithium nitrate solution 2007
The results showed that **LiFePO4** had **good electrochemical reversibility in saturated LiNO3 solution**.
Solution name: Fine lithium iron(II) phospho-olivine prepared by different methods 2007
Solution Description:
Excellent electro- chemical properties in terms of capacity, **reversibility and cycling stability** have been achieved for doped **LiFePO4** (4) synthesized by an improved solid-state reaction
Solution name: Synthesis of cathode material LiFePO4 for rechargeable lithium-ion battery by co-precipitation method 2007
The results show that Co2+ - doped **LiFePO4** is simple pure olive-type phase and it has **good electrochemical performance**.
Solution name: Preparation and characterization of LiFePO4 cathode materials by hydrothermal method 2008
Among the synthesized cathode materials, **LiFePO4** synthesized at 170 degrees C and subsequent 500 degrees C shows the **best electrochemical properties with** an **initial discharge capacity** of 167 mAh g(-1) (98% of theoretical capacity) close to the theoretical capacity of LiFePO4 (170 mAh g...
Solution name: Nano-crystalline LiFePO4 for high-performance Li-ion batteries 2003
Nanocrystalline **LiFePO4** showed very **good electrochemical performance delivering about** the **full theoretical capacity** (170 Ah kg(-1)) when cycled at C/10 rate.
savedrecs(9b).txt

Solution name: Nanomaterials for lithium-ion rechargeable batteries 2006

...nanosized composite materials, carbon nanotubes, and nanosized transition-metal oxides are all promising new anode materials, while nanosized LiCoO2, **LiFePO4** , LiMn2O4, and LiMn2O4 show higher capacity and **better cycle life as cathode materials** than their usual larger-particle equivalents.

savedrecs(6b).txt

Solution name: Lithium insertion chemistry of phosphate phases with the lipscombite structure 2005

Assuming that all the iron may be reduced, the theoretical capacity is about 180 mAh g(-1), similar to that of olivine-type **LiFePO4**. Reversible intercalation was found to proceed via a single-phase reaction at an average potential of 2.8 V versus Li+/Li. **Good structural stability** upon intercalation/deintercalation was observed

Solution name: Research Progress on LiFePO(4)-a New Type of Cathode Materials for Lithium-Ion Battery 2009

...As a new type of cathode materials for lithium-ion battery, the **olivine** LiFePO(4) has many advantages, such as abundant resources, low cost, environmental friend, higher energy density and theoretical capacity, steady discharge voltage, **good thermal stability** and excellent cycling performance, to be a strong competitor for the next...

Advantages LiMn2O4

Solution name: Electrochemical performance of surface-modified LiMn2O4 prepared by a melting impregnation method 2006

Among these samples, the ZnO-modified **LiMn2O4** shows the **best combination of** a **high capacity** and a low capacity fading rate **of** 0.036% per **cycle** at room temperature and 0.064% per cycle at 55 degrees C.

Solution name: Solution-derived lithium manganese oxide thin films with silver additive and their characterization 2007

The difference of capacity retention between the two films becomes larger with the increase of the charge-discharge current density, suggesting that the Ag-doped **LiMn2O4** has a **better cycling behavior** , especially at higher charge-discharge current density.

Solution name: Electrochemical study on LiMn2O4 as cathode material for lithium ion batteries 2006

LiMn2O4 prepared by spray-drying method showed significantly **better electrochemical characteristics**.

Solution name: Microwave synthesis of LiMn2O4 cathode material 1999

LiMn2O4 synthesized in optimum conditions delivers an initial charge capacity of 133 mA h/g, and exhibits **good rechargeability**.

Solution name: Characteristics of LiCoO2, LiMn2O4 and LiNi0.45Co0.1Mn0.45O2 as cathodes of lithium ion batteries 2005

LiCoO2 and **LiMn2O4** have higher discharge voltage and **better rate -capability than LiNi0. 45Co0. 10Mn0. 45O2**.

Solution name: Effect of PVA with various combustion fuels in sol-gel thermolysis process for the synthesis of LiMn2O4 nanoparticles for Li-ion batteries 2007

It reveals that **LiMn2O4** obtained by using PVA-urea has smaller nanoparticles and **better electrochemical performance than** the **nanoparticles** obtained by using other two combinations such as PVA-hexamine and PVA-citric acid.

Solution name: Li+ ion diffusion in LiMn2O4 thin film prepared by PVP sol-gel method 2006

The prepared **LiMn2O4** showed a **good charge -discharge performance** , and the capacity fade was ca. 20% during 200 cycles savedrecs(5).txt

Solution name: Electrochemical performance of surface-modified LiMn2O4 prepared by a melting impregnation method 2006

Among these samples, the ZnO-modified **LiMn2O4** shows the **best combination of** a high capacity and a **low capacity fading rate of** 0.036% per **cycle** at room temperature and 0.064% per cycle at 55 degrees C.

Solution name: Spray-drying process for synthesis of nanosized LiMn2O4 cathode 2006

Electrochemical measurements showed that the nanosized **LiMn2O4** reached an initial discharge capacity of 131 mAh.g(-1) at 1/5 C rate and exhibited a **good cycling property** at 1 C rate.

Solution name: Microvoltammetry for cathode materials at elevated temperatures: electrochemical stability of single particles 2000

LiMn2O4 showed **good cycle stability in** LiClO4/propylene carbonate (PC) + ethylene carbonate (EC) and **LiBF4 / PC + EC solutions** even at 50 degrees C.

Advantages LiCoO2

Solution name: Synthesis of LiA1(y)Co(1-y)O(2) using acrylic acid and its electrochemical properties for Li rechargeable batteries 2001

...temperature and reduction in the exothermic peak compared to those of Li0.5CoO2, and it indicates that Al-doped **LiCoO2** shows the **good thermal stability of** the cathode and **reduction of** the **heat of reaction**.

Solution name: Characterization of LiCoO2 coated Li1.05Ni0.35Co0.25Mn0.4O2 cathode material for lithium secondary cells 2007

This behavior implies that **LiCoO2 inhibits structural change of** Li1.05M0.35Co0.25Mn0.4O2 or **reaction** with the electrolyte on cycling.

Solution name: Crystal structures of LiCoO2 synthesized at different temperatures 2006

LICoO2 synthesized at 800 T has **better charge** and discharge **reversibility** than that synthesized at 900 degrees C. C1 Beijing Univ Sci & Technol, Dept Mat Phys & Chem, Beijing 100083, Peoples R China.

Solution name: A novel sandwiched membrane as polymer electrolyte for lithium ion battery 2007

Due to very low evaporation of the liquid electrolyte, **LiCoO2** shows **good cycling behavior in** the range of **4.4 -3.0** when this GPE is used as the separator and polymer electrolyte, and lithium as the counter and reference electrode...

Solution name: Effect of AIF(3) coating amount on high voltage cycling performance of LiCoO2 2007

The 0.5 mol% AIF(3)-coated **LiCoO2** had the **best electrochemical performance** , showing capacity retention of 97.7% after 50 cycles and rate capability of 93.1 % at 5 C discharge.

Solution name: Synthesis of LiA1(y)Co(1-y)O(2) using acrylic acid and its electrochemical properties for Li rechargeable batteries 2001

...temperature and reduction in the exothermic peak compared to those of Li0.5CoO2, and it indicates that Al-doped **LiCoO2** shows the **good thermal stability of** the **cathode** and reduction **of** the **heat of reaction**.

Solution name: Control of AlPO4-nanoparticle coating on LiCoO2 by using water or ethanol 2005

Under the influence of the AlPO4 crystallinity, the coated **LiCoO2** prepared in ethanol had **better capacity retention** than those prepared in water.

Solution name: In situ X-ray absorption spectroscopic study of Li1.05Ni0.35Co0.25Mn0.4O2 cathode material coated with LiCoO2 2007

...perturbations occurring during cycling of the novel layered system of Li1.05Ni0.35Co0.25Mn0.4O2 coated with nano-crystallized **LiCoO2** , which **effectively improved** the **rate capability**.

Lithium–air

Most promising for the electric vehicle although not yet implemented is lithium–air technology, which substitutes the heavy cathode electrode in the lithium–ion battery by a light-weight porous cathode and where the element to be used is the oxygen contained in the air. Given the lack of finance for research, the intention of the authors is not to explore all the energy storage systems, but one of the most promising, the lithium–air system (Visco et al. 2009).

In Li–ion systems, there is a prevailing technology approach, mainly consisting of a carbon-based anode, an electrolyte with a separator to avoid short circuit current and a transition alloying metal cathode. However, in the Li–air system there are still different approaches, essentially five main approaches as the organic battery, the aqueous battery, the solid battery, the mixed organic aqueous battery and the mixed organic aqueous fuel cell as presented by the team of AIST (He, Wang, and Zhou 2010, 2011).

The organic Li–air battery and the aqueous Li–air battery present several problems as pore clogging in the cathode or anode erosion (Williford and Zhang 2009), while the mixed alternative combines the advantages of both the organic and the aqueous.

To analyze other promising technology such as lithium sulphur technology, another techmining analysis is to compare the presence of research activity for the two competing technologies lithium–air vs lithium–sulphur. As mentioned before, Li–air is a promising technology because theoretically it bears the highest energy density possible, even comparable with that of fossil fuels. However, the 'breathing cathode' still is far from overcoming problems such as stability, cyclability, reduction and oxygen diffusion (Kraytsberg and Yair 2011; Padbury and Zhang 2011).

Table 9 Advantages of LiFePO4, LiCoO2 and LiMn2O4 based cathodes semantic-triz extracted results from the ISI WOS records. Firstly, is the title and Pub Year of the article where the advantage has been found.

Again, by extracting from ISI WOS research articles about Li–air and Li–sulphur in electric vehicles, Figure 12 shows a comparison in research activity based on the number of published articles for lithium–air and lithium–sulphur technologies. As shown, there is continuously increasing research activity in both technologies, although a steeper increase in lithium–air technology is apparent. Although not shown, the same analysis shows an increasing number of manufacturing companies involved in Li–air research activity: 12 articles in 2009, 23 articles in 2010 and 41 in 2011. There is a strong presence of companies such as Samsung, Toyota, Saft batteries and recently, IBM Research to name but the most prolific. There is no similar intense effort among automotive firms in Li–S research articles.

Within the lithium–air technology, it is interesting to see the increasing presence of the material graphene because of its conductivity and capacity to incorporate other materials as catalysts (Song et al. 2011), shown in Figure 13.

Another interesting subject in the Li–air technology is to determine the trend of the prevailing or dominant model (Teece 1986) between the organic type of Li–air battery and the aqueous Li–air battery. Each model has its advantage and its drawbacks. Figure 14 shows the presence of each one exhibiting an almost equivalent presence. The mixed model, organic–aqueous, is not very evident from the data analyzed to obtain a clear trend.

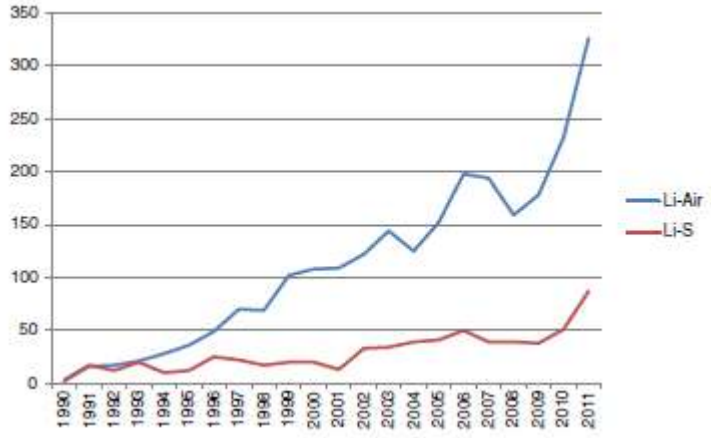


Figure 12. Prevalence of Li-air vs Li-sulphur (number articles per year.

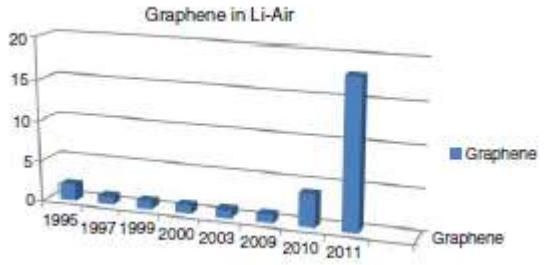


Figure 13. Introduction of material graphene in Li-air electrodes research activity (number of articles per year).

Here the semantic-TRIZ analysis of the ISIWOS articles (either Li–air, Li–S or Li–ion from the queries) can provide some of main uses of graphene and especially within the Li–air for different years. In that sense, it complements the quantitative trend of the results obtained by Techmining. Table 10 shows the main applications of graphene from the research articles. By tracking the uses of the technology by year, one can determine the primary purpose in a brief time and thus show some benefits of combining techmining with semantic-TRIZ. Techmining detects the research effort measured by the number of articles published per year of a given technology and semantic–TRIZ among different elements can extract the uses of such technology on a yearly basis, giving a clearer image of what the advances and possibilities are in a convenient way.

As a second example to illustrate the advantages of combining Techmining and semantic-TRIZ, the authors have identified an increasing trend in the use of nanostructures within the lithium–air research activity. Figure 15 shows the emergence of nanostructures and Figure 16 shows the increasing share of the cited nanostructures within the Li–air research activity.

Once the increasing presence of nanostructures has been identified, it is relevant to explore the application and uses of the cited nanostructures to understand better their role in the lithium batteries. The same ISIWOS records mined from VantagePoint in Li–air have been syntactically analyzed with semantic-TRIZ, extracting the functions and relationships of the nanostructures as nanoscale systems capable of performing functions. Some of the useful functions are applications and a selected sample of them has been plotted in Table 11. It is possible to obtain a deeper understanding of the possible changes and rationale of a new technology by exploring the evolution of applications as well as other functions in a certain period. Semantic-TRIZ analysis also offers the possibility of prospecting future extensions of a technology by understanding the uses and functional links with existing or additional elements.

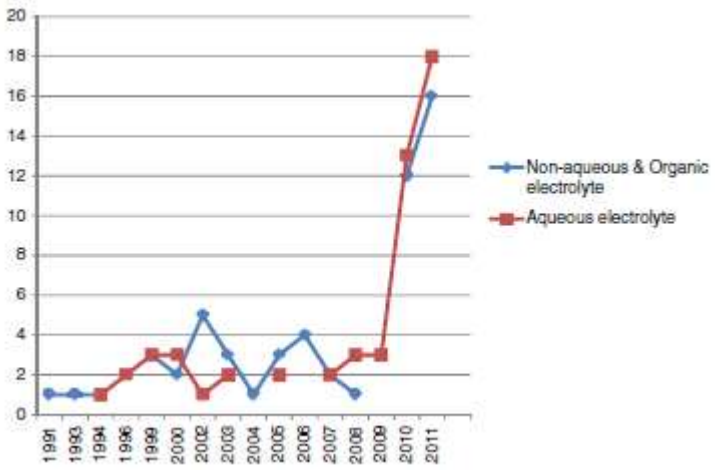


Figure 14. Aprotic or organic Li-air vs aqueous Li-air (number of articles per year).

Table 10. Uses of graphene from the ISI WOS research articles Li-Air and Li-S, with the title of the article and the publication year as solution name.

Within Li-Air systems
Solution name: Li-Air Rechargeable Battery Based on Metal-free Graphene Nanosheet Catalysts 2011 **AB Metal -free graphene nanosheets** (GNSs) were examined for use as air electrodes in a U-air battery with a hybrid electrolyte. **Solution name:** Facile, mild and fast thermal-decomposition reduction of graphene oxide in air and its application in high-performance lithium batteries 2012 **pure V2O5/graphene composite** Applying the advantage of this strategy that provides an oxidizing atmosphere, **pure V2O5 / graphene composite** is successfully synthesized and exerts excellent lithium storage properties. **Solution name:** Multifunctional materials based on graphene-like/sepiolite nanocomposites 2010 The **graphene -like sepiolite nanocomposites** can be used as electrode materials for rechargeable lithium batteries, showing better cyclability and Li-insertion properties than the nanostructured carbon without the silicate counterpart.

Within Li-S systems (Li-S query ISI WOS) as an example complementing the functions found for li-air.

Solution name: A facile method of preparing mixed conducting LiFePO(4)/graphene composites for lithium-ion batteries 2010

The comparative investigation on **LiFePO4 / graphene composites** and LiFePO(4) proved that establishing a mixed conducting network with graphene has a potential to enhance the specific capacity and rate capability of LiFePO(4).

Solution name: Graphene Oxide as a Sulfur Immobilizer in High Performance Lithium/Sulfur Cells 2011

Graphene Oxide as a Sulfur Immobilizer in High Performance Lithium/Sulfur Cells

Strong interaction between graphene oxide and sulfur or polysulfides enabled us to demonstrate lithium/sulfur cells with a high reversible capacity of 950-1400 mA h g(-1) and stable cycling for more than 50 deep cycles

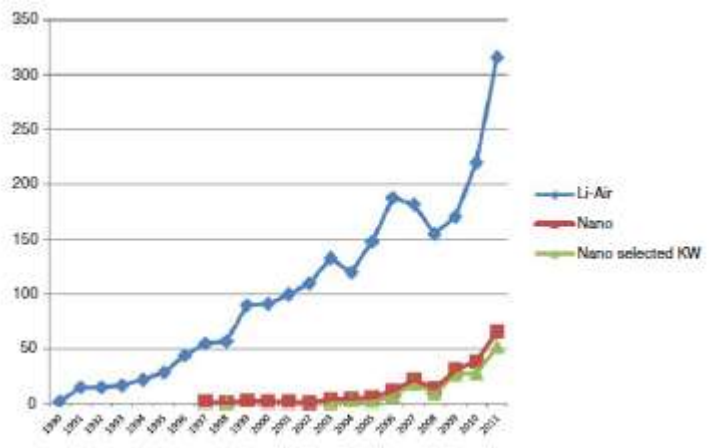


Figure 15. Trends in research with nano within lithium air research (number articles per year).

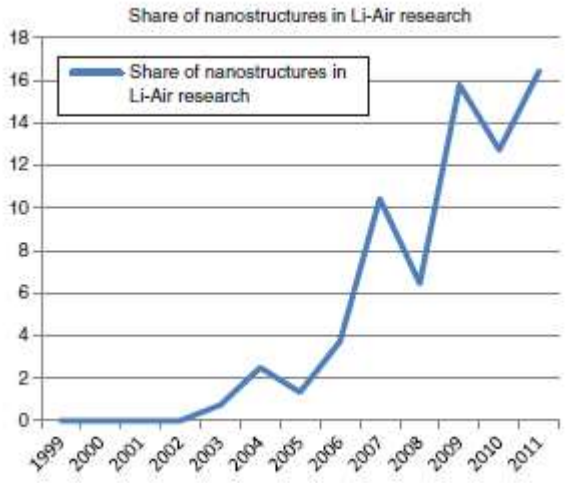


Figure 16. Share of nanostructures within the Li-air research activity (articles containing nanostructures vs total articles Li-air) by year.

Table 11. Some uses of nanostructured elements.

Application	Source paragraph	Article Title	Publication Year
reacting with lithium__electrochemically active in lithium cells	The **nanotube**s react with **lithium** chemically and are also **electrochemically active in lithium cells**	Manganese vanadium oxide nanotubes: Synthesis, characterization, and electrochemistry	2001
as **electrode material**	...Oxidative Stress; Cytotoxicity; ROS ID GAMMA-MNO2; BETA-MNO2; ADULT; ROUTE; OXIDE AB alpha-Manganese dioxide (alpha-MnO(2)) **nanowires** are used as **electrode materials to significantly enhance the performance of lithium batteries**.	Mechanism for alpha-MnO(2) Nanowire-Induced Cytotoxicity in Hela Cells	2010

Application	Source paragraph	Article Title	Publication Year
as **sensing material in fabrication** of LPG sensor	The experimental results clearly demonstrate the potential of using the **alpha-Fe(2)O(3) nanorods as sensing material** in the fabrication of LPG sensors.	Highly sensitive and selective LPG sensor based on alpha-Fe(2)O(3) nanorods	2010
monitoring of concentration of CO	Furthermore, the Co(3)O(4) **nanorods** are able to detect **up to 5 ppm for CO with reasonable sensitivity** (similar to 3.32) at an operating temperature 250 degrees C and they can be reliably used to monitor the concentration of CO over the range (5-50 ppm).	Highly sensitive and fast responding CO sensor based on Co(3)O(4) nanorods	2010
monitoring of concentration of LPG	... the alpha-Fe(2)O(3) nanorods are able to detect up to 5 ppm for LPG with reasonable response (similar to 15) at the operating temperature of 300 degrees C and they can be reliably used to monitor the concentration of LPG over the range (5-60 ppm)...	Highly sensitive and selective LPG sensor based on alpha-Fe(2)O(3) nanorods	2011
as electrode reaction catalyst	...J AU Li, WY Liu, JG Yan, CW AF Li, Wenyue Liu, Jianguo Yan, Chuanwei TI Multi-walled carbon **nanotubes** used as an **electrode reaction catalyst** for VO(2)(+)/VO(2+) for a vanadium redox flow battery SO CARBON LA English DT Article ID LITHIUM...	Multi-walled carbon nanotubes used as an electrode reaction catalyst for VO(2)(+)/VO(2+) for a vanadium redox flow battery	2011
as electrode reaction catalyst for VO + /VO redox couple	...redox flow battery SO CARBON LA English DT Article ID LITHIUM-ION BATTERIES; CELL AB **Pristine multi-walled carbon nanotubes** (MWCNTs), and those functionalized with hydroxyl groups, or carboxyl groups were used as **electrode reaction catalyst for**	Multi-walled carbon nanotubes used as an electrode reaction catalyst for VO(2)(+)/VO(2+) for a vanadium redox flow battery	2011

Application	Source paragraph	Article Title	Publication Year
	VO(2)(+)/VO(2+) redox couples for vanadium redox flow battery		
retainment of reversible capacity	After 20 cycling tests, the **activated carbon nanotube** retains **a reversible capacity of 728 mAh g(-1).**	Lithium storage performance of carbon nanotubes prepared from polyaniline for lithium-ion batteries	2011

Figure 17 shows the cooperation networks between automobile corporations and other players, which may indicate the involvement of business corporations for the Li–air technologies as seen in its system (Visco, Nimon, and De Jonghe 2009). Cases like Samsung group (47% of its publications) or Toyota (41% of its publications) shows the visible presence of the open-innovation approach.

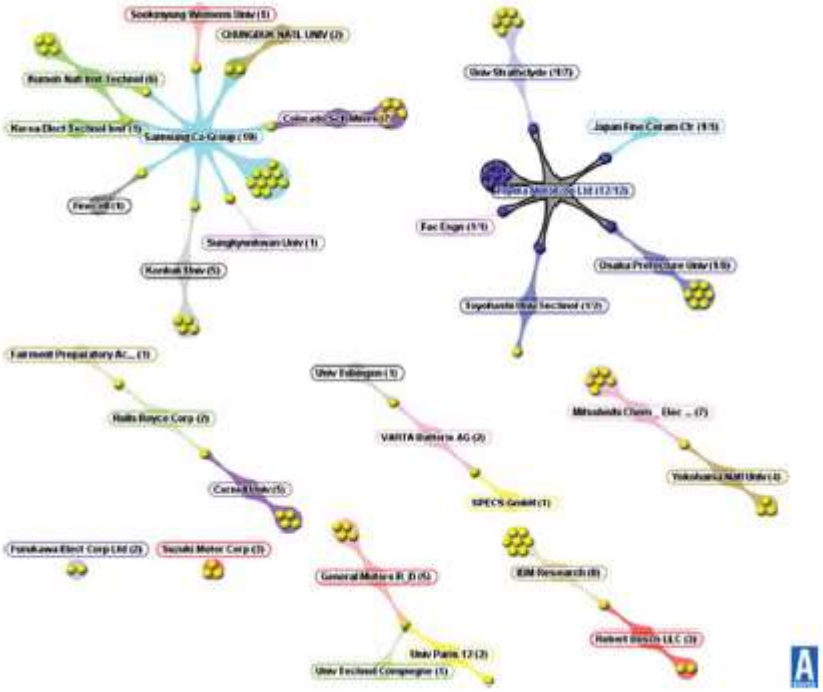


Figure 17. Network (co-ocurrences) of corporate research institution collaborations with more than one article within Li-air for electric vehicles.

Figure 18 shows a second wave of increasing presence of corporate research in the latest years, which may also reinforce the previous idea.

As a complementary way to understand the current state of a technology, the systemic point of view of TRIZ helps to understand current functional limitations, which can be complemented with weak signals, emergent or trend technologies, obtained from the Techmining analysis. In that sense, Figure 19 shows the functional systemic diagram of

an Li–air fuel cell as presented by He, Wang, and Zhou (2010). The components in rectangles are elements within the system, while the ovals, two in Figure 19, are the target of the system, i.e. what the system is intended for.

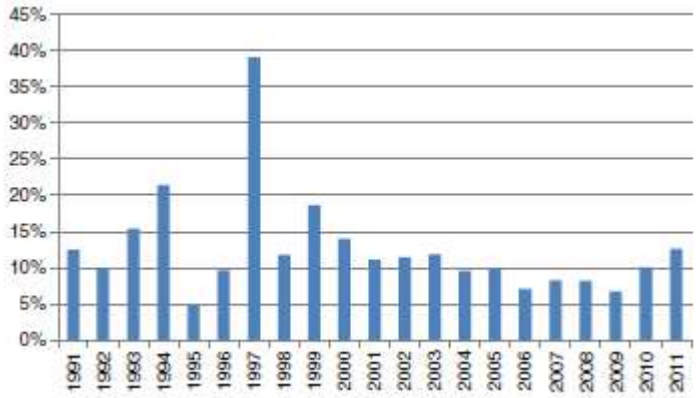
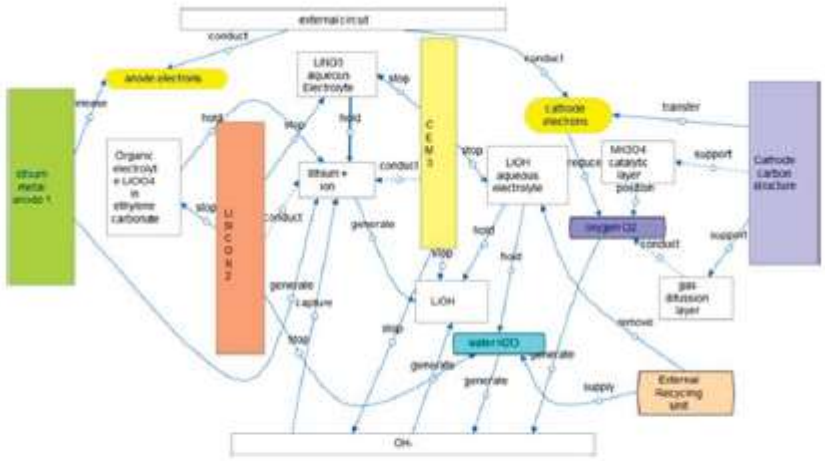


Figure 18. Corporate research by article publication as percentage of the total Li-air.



Source: Own elaboration from Wang, and Zhou (2010), He, Wang, and Zhou (2010, 2011) and Song et al. (2011). LISICON is an ionically conductive material selective to lithium ions. It may comprise a class of lithium conductive ceramics which include: $Li_{2+2x}Zn_{1-x}GeO_4$ ($-0.36 < ; \times <;0.87$), $Li_{14}ZnGe_4O_{16}$, and slight variations in stoichiometry and with amounts of cation substitution. Source: US-20100068629 A1 alkali–metal–seawater battery; CEM 3 is a cation exchange membrane.

Figure 19. Systemic functional diagram of a Li-air fuel cell.

The arrows represent the actions where the donor is changing some parameter of the receiver. It is necessary to build the diagram in a correct functional way from the TRIZ point of view. The dotted arrows represent the inadequate, insufficient functions and so show areas to improve in the current system.

Such systems show several conflicts or contradictions as known in TRIZ, which identify room for improvement, e.g. to preserve the LISICON membrane from an alkaline solution, a second cation exchange membrane is added, but this increases cost and reduces efficiency by hindering the diffusion of Li+ (dotted arrows). A second current limitation or conflict is that the LISICON membrane separates the aqueous solution from the Li anode which is a need, but it also increases cost and again hinders the movement or transport of Li+, reducing the overall efficiency. From these current issues, some trends are showing Figure 20 where all terms related to oxygen diffusion or ion transport have been plotted to show some increasing research interest as some of the current limitations of the system.

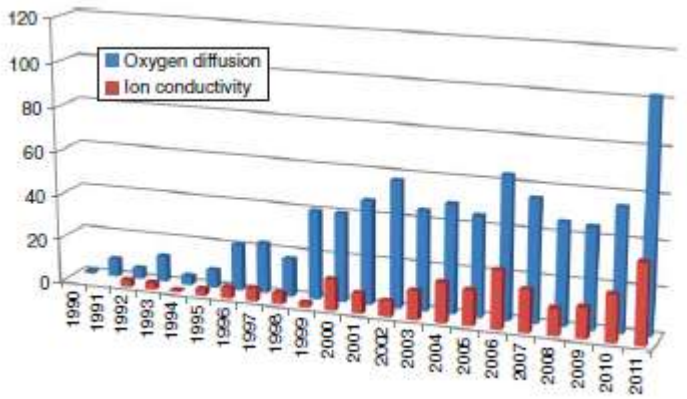


Figure 20. Research effects in two limiting functions of the fuel cell functional diagram from Figure 19.

Conclusions

The combination of techmining, which can extract trends, emerging topics and also identify collaborations, can be complemented with the help of semantic-TRIZ to understand applications, causes and effects of any relevant technology in a brief time, offering even to non-experts a better understanding of that technology. By analyzing – as a way of example – the field of lithium based batteries as a part of energy storage systems for electric vehicles, the present research work pretends to show the initial possibilities of identifying trends and complementing them with understanding the current system limitations, the knowledge of applications and main functions of such trends. This combination has been applied to understand the emergence of research in LiFePO4 cathode materials and its key uses or parameters, which can help to understand the increasing interest in research. Another example was trying to understand the increased presence of graphene in batteries with its functionalities within the battery (Brownson, Kampouris, and Craig 2011). The third example was to explore the presence of nanostructures and their uses to understand the increasing research interest.

This is a first attempt to explore the advantages of the combined analysis without pretending to be exhaustive in the samples retrieved. More research should be done to test other synergies of Techmining and semantic-TRIZ. We hope that other contributors will enrich this field.

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Chapter 7
Is semantic TRIZ applicable in the process of complementary literature discovery?

The contribution of syntactic-semantic approach to the search for complementary literatures for scientific or technical discovery.

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Abstract

The present paper tries to show that the current state of the art in syntactics and semantics, in computer systems based on the theory of inventive problem solving known as TRIZ, may help in the task of literature based discovery. With a structured and logic cause linkage between concepts, LBD could be faster and with less expert involvement at the beginning of the LBD process. The author tries to demonstrate the concept with two different problems: the hearing and balance problem known as Meniere's disease, and to some of the current problems in the lithium air batteries for electric vehicles. By using open literature based discovery from An to Bn and from Bn to Cn, and with the logic relationships of real causes and effects approach, the author finds several relative new concepts such as *vitamin A*. Other concepts as niacin or fish oil, are also found, as

potential to help in the Meniere's disease. Secondly, using such procedure the author is able to find patents from disparate domain of expertise, as patents about *odor control* or *metal casting*.

Introduction

The use of Tech Mining and its power to elucidate information in new ways, as a new idea trigger (Porter and Cunningham 2005) and with that for resolving problems (Kostoff, 2011), stimulate scientific discovery (Swanson and Smalheiser 1997) and to assess scientific discovery (Smalheiser and Swanson 1998; Swanson 2008) has been successful up to date. In the case of literature based discovery, LBD, its systematic approach continues to be a blueprint for finding most of the potential prior unrelated concepts. However, it is a time-consuming task, which needs to read hundreds of documents to identify and to validate linkages from a first concept A to a second concept B, and from the second B to a third concept C. Text mining tools help a lot by extracting terms and multiterms, their frequencies and other dimensions, but they need to extract them from titles and abstracts, losing the opportunity of hidden relationships in full texts of the research papers. Besides, the researcher needs to find what relationship exists between concepts in order to discover any potential concept.

There are mainly two procedures for literature based discovery; one is the *open discovery approach* where the research starts with one problem and arrives to a solution from disparate literature and the *closed discovery approach* where the research starts with a problem and a solution and then tries to find a reasonable connection between them (Kostoff et al. 2008). The present paper mainly uses the open discovery approach. It attempts to arrive to a potential example solution by identifying logic links extracted from the sentences of researchers from different areas or disciplines.

In the classic approach to knowledge discovery, B terms are identified either by frequency (Swanson and Smalheiser 1997), expert judgment (Kostoff, 2006) or by text similarity (Gordon and Dumais 1998). In the S-S or semantic TRIZ approach, terms are analyzed by their logic relationships based on a chain of functional related terms, a chain of cause-effect related terms, and ontologies. Therefore, starting from one problem or one disease, one can find causes or subjects acting on the disease (Raynaud's as in the classic or other diseases). Most of LBD work published to date works mainly with structured text from database records. Semantic TRIZ however, allows working with full unstructured text. Such approach offers a new dimension in analyzing texts to find relationships in different literatures.

The contribution of syntactic linking to relate initially disparate literatures can help to ease the potential discovery of new knowledge, by finding links with human like logic sense. With explicit logic links and true cause-effect relationships, less expert judgment may be needed to discover new knowledge in comparison with the identification of relationships in the term based literature discovery. However, as the S-S or semantic TRIZ at its current development state, cannot ascertain the extraction of all the possible logic

relationships, S-S TRIZ cannot be yet a replacement to LBD but to complement some steps of the traditional literature based discovery.

The TRIZ theory, the Russian acronym for Theory of Inventive Problem Solving, understands the technology as 'systems' where every system is a group of functionally related parts or elements which jointly perform a function or an action to a receiving element or 'target of the system'. (Altshuller 1984) For instance, the system 'pump' and the target 'water' are linked by the function 'to move': *a pump moves water*. That approach helps to see the relationships of any substance or concept as a 'system' which performs some action to a target substance or part of the human body and, therefore, to understand the use of a concept, or what type of result or the effect it may produce. By applying this concept of a 'system' "performing some action", to the texts found in patents, science papers, etc., one can start to understand the meaning and relationship between concepts in the literature. This is the basic concept of Syntactic-Semantic TRIZ, or S-S TRIZ (Verbitsky 2004), powered with the commercial software tool GoldFire of IHS Denver CO. Such linking relationships can make logic sense to a researcher and may help to link disparate literatures in the sense of knowledge discovery in the published related literature.

By means of using the syntactic and semantic TRIZ based approach, the author tries to identify Bn concepts linked to a given concept An and afterwards, the relationship between Bn to a third concept Cn respectively by means of the semantic logic relationships. Once a sensible indirect or logic chain of relationships is identified, between the known An and the newly found Cn, the next step is to see if such Cn can be a potential discovery. By exploring a non- direct interaction between An and Cn, either by lack of citation of An concepts in the literature containing the Cn terms or lack of Cn concepts in the literature containing the An terms, in both cases by analyzing the full texts.

The use of S-S TRIZ permits to identify a more accurate relationship of logical causes and effects beyond any subject-action-object SAO connection, as also recently used (Kim et al. 2010, 2012). The advancement of natural language processing NLP algorithms and linguistic rules for NLP, allows for a more accurate retrieval and assessment of real causes and effect phenomena (Todhunter et al. 2010). However, there is a possible limitation in applying S-S TRIZ to the medical literature since what can be associative in technology literature needs to be carefully evaluated in the medical related literature and clinically tested. Therefore, not any SAO can be meaningful in medical literature and may need more expert assessment.

As an example, let us assume that a full text research article has among its paragraphs the following sentence: "*resveratrol is contained in red wine, and can improve cardiovascular health; it blocks cholesterol oxidation and inhibits low density cholesterol*" The S-S TRIZ approach implemented in the commercial tool GoldFire, would recognize structures such as shown in table 12.

Table 12. Concepts extracted from a regular sentence.

- resveratrol (An) improve cardiovascular health (Bn or Cn) - resveratrol (An) blocks cholesterol oxidation (Bn or Cn) - red wine (An) contains resveratrol (Bn or Cn) (*mereology*)

From the former logic links, one can identify logic meaning to such relations, without the need of explicit words like cause or effect. With a chain of logic links, hidden relationships could be identified. Even more, meaningful concepts or sentences embeded in any paragraph of a full text research article can be processed to extract logic relationships.

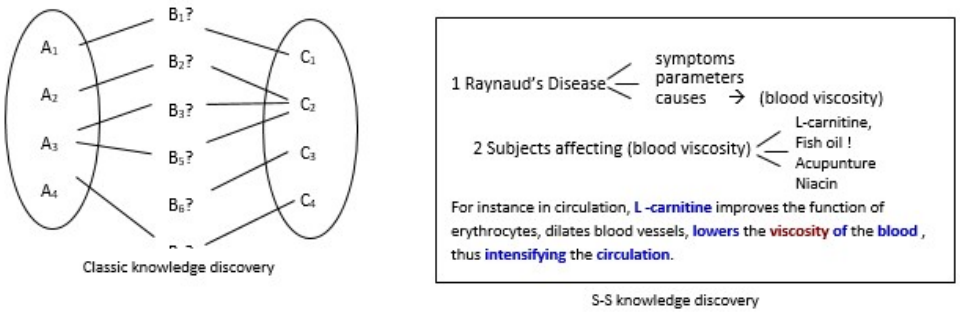

Figure 21. Conceptual scheme of difference in term relationship and syntactic-semantic relationships.

Although the medical and technical non-medical literature may seldom use literally the terms 'cause' or 'effect', by identifying that 'a pump moves water' one can understand that the 'effect' or consequence of moving water may be 'caused' by a pump. Figure 21 shows the difference in literature based discovery by terms without clear linkage meaning or semantically cause –effect chains related terms and the syntactic-semantic approach with meaning verbs linking concepts. In figure 21, the causality relationship between 'blood viscosity' and 'L-carnitine' can be deducted from the automatically extracted sentence 'L -carnitine improves the function of erythrocytes, dilates blood vessels, lowers the viscosity of the blood, thus intensifying the circulation'. Here, the term 'L-carnitine' would be in the list of interactions with the term 'blood viscosity'. It is not because both terms are near in sentence, but because there is a logic human-sense interaction between L-carnitine and blood viscosity.

For instance, to identify *causes* performed or received by any term or concept, the S-S TRIZ approach will identify actions or relationships of the type for example: *produced by*, *results in*, *yields*, *caused by*, *the 'result' is the outcome of,* etc. In every case, the receiving concept will be the *effect* and the acting concept will be the *cause*. S-S semantic TRIZ can also identify and list interactions that should be examined for possible causality. For instance, in the article of Suzuky et al. 2003, one of its paragraphs states: '*…These reports presented evidence that the etiology and pathogenesis of certain inner diseases, for example, Meniere's disease and progressive sensorineural hearing loss (PSNHL), might be related to autoimmunity, but have not yet fully confirmed the autoimmune pathological mechanisms…"* the S-S approach would find an interaction 'Meniere's disease *might be related to* autoimmunity'

In the case of applying the S-S TRIZ to a technology or a technical system, the author takes into account the systemic view of TRIZ to understand the different hierarchy of the relationships, beyond the cause-effect sense (Kim H., Kim K.; 2012) or the subject-action-object SAO relationship (Choi et al. 2011). In TRIZ, not all the relationships of a system are of the same relevance. Its relevance depends on its proximity to the main function of the system, i.e. that aiming to the target of the system. For instance, the main function of a water pump may be to move water by increasing its pressure. Other internal functions, i.e. SAO relationships internal of the pump, although needed, they have not the same relevance in terms of functionality and therefor of relationship. It is to notice that the main function of a system is based on the functioning principle of said system (Rubin et al. 2011) and its relevance in the linkage or relationship of elements within a system. Returning to the example of the water pump, the impeller is the element which uses centrifugal force (principle of the system) to increase the pressure of the water and hence, to move it. Thus, the main function of the water pump is to move water (liquids), and such function is based on the centrifugal force.

It is left to further research whether medical diseases, as Meniere disease or at least parts of the body involved in the disease, can be also analyzed as a true system in the TRIZ systemic point of view. It seems reasonable to think that a chain of body elements and its effects are responsible for a disease, although in not few cases that mechanism remains unknown or not mentioned in the medical body of knowledge. (Kostoff et al. 2008) In the latest years, LBD has made an attempt to broaden the scope of search for not related literature by trying to use functional synonyms (Kostoff et al. 2008), however, the text mining approach could not identify function relationships automatically.

In order to increase the possibilities of extracting all potential solution for a given problem, classical LBD needs to expand the literature around such problem by using co-ocurrences, citations and references, and functional synonyms, (Kostoff et al. 2008) Since there are not relationships between the terms in the classic LBD, the researchers need to expand the literature within certain limits for reducing the risk of missing all the possible potential discovery, and for assuring a manageable amount of literature and time resources dedicated.

The author thinks that with logic relationships and functional relations, there is less need to delimitate the potential literature for discovery since the semantic TRIZ approach can process thousands of full texts to find causality chains, in the broad sense discussed in this paper, For every new cause extracted, a new comprehensive search can be done to find the next cause 'causes and so forth. Therefore, it is possible to reach almost all possible connections in a large literature analysis, limited only by the current capacity of the semantic NLP technology to extract all the relationships available.

Data and methods

To demonstrate the advantages of using S-S TRIZ, the author has mined 499 full text papers from Elsevier Science Direct using the MESH terms equivalent to *Meniere disease* and using them as query terms in the search strategy, title + abstract + keywords; last date is 06-08-201. Also, the term *Endolymphatic sac*, and more concrete the term *Endolymphatic duct* has also been searched (Sajjadi M. and Paparella M., 2008) as query term in Elsevier Science Direct in advanced search, title + abstract + keywords, mining 78 full text papers available to the author, out of 87 respectively retrieved from Elsevier. Mining all the entire articles mean indexing all paragraphs of every article and extracting all the system relationships as in table 12. However, the author cannot make sure that the current state of the art of the S-S TRIZ software can extract all the relationships as a human can, but it can analyze thousands of articles and extract a great percentage of logic relationships.

Figure 22. Image of a fragment of the list of causes extracted from the mining of 499 full text articles about Meniere disease.

Figure 23. A single 'cause' record, extracted from the fragment of the list shown in figure 22, showing that within a document more similar 'causes' can be identified, shown as a link.

Figure 22 shows an image of the list of causes extracted and figure 23 is an example of one of the causes seen in figure 22, expanded. As can be seen in figure 23, there are no words 'cause' or 'effect', however, the result that Meniere's disease is an outcome of a mutation is automatically linked as cause and a human can interpret and agree or not such link. The software could extract 48 causes and 86 interactions of the type subject-action-object, which need to be explored. Not all the causes or interactions may have logic meaning, however as such interactions are not human driven; it is worth to explore them. The logic chains obtained by S-S TRIZ, avoid many relationships of terms without significance and make sense in selecting possible solutions or approaches.

Once all the possible causes were extracted for the term -system- 'Meniere disease', some of them were manually selected as an example to demonstrate the approach of S-S TRIZ and the mechanisms of relationships. Among the selected causes, one can read for instance, causes as: *Eustachian tube blockage*, *imbalance of fluid* in the inner ear, *endolymphatic duct hydrops*, etc. It is not the purpose of the author to perform a full LBD exercise at this time but to show that the logic links between terms extracted with S-S TRIZ, help to understand if it can be a real cause or not at almost first sight. Moreover, as the extraction is not human driven the relationships can be also serendipitous and may bring unexpected results, which need to be examined.

To find further chaining links to Meniere's disease, the author selected the Meniere's disease cause '*Eustachian tube blockage'* and explored to find links to that cause. The following step was to find candidate systems, which interacted or affected the – object' logic cause *Eustachian tube blockage*. Again, a list of causes, effects or interactions could be extracted with the help of the software. In this case, instead of causes of Eustachian tube blockage, we had to explore acting subjects whose object was the Eustachian tube blockage. By exploring those links, the author could select those with logic meaning, being more probable to have a meaning also for an expert. If there is any element Cn capable of effecting the Eustachian tube blockage (Bn), and being the latter a cause of Meniere's disease (An), then one can infer the relationship straightforwardly between Cn and An.

Also, to demonstrate the possibilities of S-S TRIZ in the industrial domain, the author focused in the domain of electric vehicles energy storage systems, in particular in the lithium air batteries as an example of analysis. For such purpose, the following query CTB=(lithium ADJ air ADJ battery) OR CTB=(li-air ADJ battery) OR CTB=(li-air ADJ energy) AND DP>=(20000101); in the database Thomson Innovation (www.thomsoninnovation.com) was used. This query retrieved 98 patent families –all patents with the same priority date form a patent family- from year 2000 to present, to avoid duplications. The result of the retrieved patents was also analyzed. Besides, the author took advantage of the default already mined patent database of the software tool GoldFire which covers the indexed full text of patent documents, applications + granted, mainly from the USPTO, the European patent system and the Japanese National Office from 1970 to date. The purpose was to search for possible concepts from other 'foreign' technological domains.

Development and Applications

As stated before, it is neither the purpose of this paper to extract all possible solutions, as in most of the literature-related discovery methods (Van der Eijk, C. et al 2004, Kostoff, 2008, Swanson 2008, Perkins 2009), nor even to extract a real demonstrated medical solution. The present paper tries to show that, with the aid of S-S TRIZ approach, the task of finding solutions may be easier and may contribute as a first step or a complement, in the traditional LBD process. Another benefit to be shown is that experts could be involved later in the process and with less degree of implication. Previous semantic and natural language process techniques (Feldman et al. 2003) have put the emphasis on using visualization tools to show the relationships between terms, but still did not take advantage of the syntactic approach such as in S-S TRIZ. Choi et al. 2011, Yoon J. and Kim K. 2012, used a SAO approach to elaborate a network of subject-action-object relationships to discern technology trends. The SAO approach, used a former less developed tool named Knowledgist. This tool linked all candidate subjects with all possible objects relying to humans to examine them for finding meaning or significant relationships among all possible relationships. Goldfire is the resulting evolution of the software tool Knowledgist, both of the commercial firm Invention Machine now IHS.

Returning to the case of Meniere disease, equivalent to An in figure 21, table 12 shows a retrieved group of selected causes, as an example of all possible causes extracted. For the present work, the tool used the standard default medicine ontology, containing medical terms by which all the possible causes were extracted. The ontology is needed for a correct semantic and syntactic extraction of relationships cause-effect, part of, interaction, etc. The introduction of medical terms specific or related to a given disease would have enriched the ontology, and so better and even more causes or interactions, could be automatically extracted (Rimell and Clark 2009, Coulet et al. 2010).

Table 13. Causes of the term 'An' Meniere disease.

Relation-ship or link	**Meniere's disease causes**	**Source**
provoked by	One form of the psychosomatic hypothesis suggests that Meniere's **disease** may be provoked by **stress**.	Stress and symptoms of meniere's disease: A time-series analysis Gerhard andersson,*† christina ha¨ gnebo† And lucy yardley *Journal of Psychosomatic Research,* Vol. 43, No. 6, pp. 595–603, 1997
can cause	**There is little evidence, if any, whether head or ear injuries can cause Meniere's disease a number of years later or whether such incidents are just coincidental.**	CHE Guidelines for Meniere's Disease 1995 **Otolaryngology-Head and Neck Surgery 835 june 1996**
may be caused by	Meniere's **disease** may be caused by common **intraosseous dental pathology** – Diagnosis using the comparative compression sign	Meniere's disease may be caused by common intraosseous dental pathology – Diagnosis using the comparative compression sign 2007 Medical Hypotheses (2007) 68, 389–392 David Eidelman
may be caused	that Meniere's **disease** may be caused by **allergic hypersensitivity reactions to either inhalant allergens or foods**	Immunologic aspects of Meniere's disease 1999 Michael J. Ruckenstein, MD, MSc, FRCSC, FACS American Journal of Otolaryngology, Vol20, NO 3 (May-June), 1999: pp 161-l 65 161
may have a significant role	**immunologic factors** may have a significant role in triggering Meniere's disease.	Immunologic aspects of Meniere's disease 1999

Relationship or link	**Meniere's disease causes**	**Source**
		Michael J. Ruckenstein, MD, MSc, FRCSC, FACS American Journal of Otolaryngology, Vol20, NO 3 (May-June), 1999: pp 161-l 65 161
occurs due to	Tumarkin [7] stated that Meniere's **disease** occurs due to **intermittent Eustachian tube blockage** and speculated that inadequacy of equilibrium on the part of the Eustachian tube may be involved, possibly leading to...	Eustachian tube function in patients with Meniere's disease N. Kitajima et al. / Auris Nasus Larynx 38 (2011) 215–219
leads to	It is possible that they are two separate diseases that exist coincidentally or that the **endolymphatic hydrops** that leads to Meniere's **disease** is **caused** by the **otosclerotic process**	Case report Meniere's disease and otosclerosis—Different outcomes of the same disease T. Klockars, E. Kentala / Auris Nasus Larynx 34 (2007) 101–104
are caused by	Evidence suggests that many cranial nerve syndromes, such as migraine headache, acute vestibular neuronitis, globus hystericus, carotidynia, acute facial paralysis (Bell's palsy), and Meniere's **disease** , are caused by the **neurotropic herpes simplex virus** (HSV).	Otolaryngol Head Neck Surg (1979). 1980 May-Jun;88(3):270-4. Herpes simplex polyganglionitis. Adour KK, Hilsinger RL Jr, Byl FM. Pub med
might be the cause of	It has been proposed that **compression of** the auditory and **vestibular nerve trunks by vascular loops** might be the cause of otherwise unexplained hearing loss, tinnitus, and vertigo, as well as Meniere's **disease**.	**MEDLINE/PubMed Abstracts:** The anterior inferior cerebellar artery in the internal auditory canal. Laryngoscope. 1991 Jul;101(7 Pt 1):761-6. The anterior inferior cerebellar artery in the internal auditory canal. Reisser C, Schuknecht HF. Source

Relationship or link	**Meniere's disease causes**	**Source**
inducing	**Analysis of** the main **components of inner ear antigens** inducing autoimmune Meniere's **disease** in guinea pigs	**MEDLINE/PubMed Abstracts:** [Analysis of the main components of inner ear antigens inducing autoimmune Meniere's disease in guinea pigs]. Zhonghua Er Bi Yan Hou Tou Jing Wai Ke Za Zhi. 2008 Aug;43(8):596-600. Lu L, Tan CQ, Cui YG, Ding GP, Ju XB, Li YJ, Cai WJ. [Article in Chinese]
may be mediated by	A growing body of evidence suggests that some cases of Meniere's **disease** may be mediated by **immune mechanisms**	Immunoperoxidase study of the endolymphatic sac in meniere's disease John L. Dornhoffer MD[1,*], Milton Waner MD[1], I. Kaufman Arenberg MD[3], Donna Montague[2] **The Laryngoscope** Volume 103, Issue 9, pages 1027–1034, September 1993
can lead to	In 1943, Altmann and Fowler6 concluded that **problems** in production and absorption of endolymph can **lead to Meniere 's disease**.	Meniere's disease review 2008 Hamed Sajjadi, Michael M Paparella www.thelancet.com Vol 372 August 2, 2008
have been associated with	Specifically, **human leucocyte antigens** (HLA), B8/DR3 and Cw7, have been associated with **Meniere 's disease**	Chapter 28 - Ménière's disease Handbook of Clinical Neurophysiology, Volume 9, 2010, Pages 371-381 John P. Carey
might be the cause of	It has been proposed that **compression of** the **auditory** and vestibular **nerve trunks by vascular loops** might be the cause of otherwise unexplained hearing loss, tinnitus, and	Laryngoscope. 1991 Jul;101(7 Pt 1):761-6.

Relationship or link	**Meniere's disease causes**	**Source**
	vertigo, as well as Meniere's **disease**.	The anterior inferior cerebellar artery in the internal auditory canal. Reisser C, Schuknecht HF
are thought to be produced by	The symptoms of Meniere's **disease** vertigo, hearing loss, and tinnitus—are thought to be produced by a **sudden influx of fluid into the endolymphatic sac**, producing a rupture of Reissner's membrane in the cochlea.	Prevalence of allergy in Meniere's disease M. Jennifer derebery, md, facs, and Karen i. Berliner, phd, Los Angeles, California Otolaryngology– Head and Neck Surgery July 2000
plays a role in	It is well established that **endolymphatic hydrops plays** a **role in Meniere disease**, even though the precise role is not fully understood and the presence of hydrops in the ear does not always result in symptoms of the disease.	Endolymphatic Hydrops: Pathophysiology and Experimental Models *Otolaryngologic Clinics of North America*, *Volume 43, Issue 5*, *October 2010*, *Pages 971-983* Alec N. Salt, Stefan K. Plontke

Table 13 is a selection of causes, for the purpose of demonstrating how the S-S TRIZ can establish logic links of cause effect between the An term 'Meniere disease' and different Bn terms. It is not necessary that the original paragraph or sentence, clearly states the terms 'cause' or 'effect'. The first column of table 13 shows some of the relationships that can be interpreted as causes, by common sense.

By selecting one of the causes or Bn, again as an example to show the approach, e.g. *intermittent Eustachian tube blockage,* then the next task was to find *systems* or concepts or Cn, able to perform some effect on Bn. In the present example, it meant to find some element capable of performing some effect on *Eustachian tube blockage*. Again, not every relationship or SAO was a valid effect, especially in the medical literature. The tool extracted a list of 36 causes + interactions affecting the Eustachian tube blockage or even to the Eustachian tube itself. Table 14 shows a selected group of causes or interactions i.e. acting elements Cn, on the concept Eustachian tube or its blockage. Not all the possible terms and their connections were extracted but those who had an explicit relationship, according to the linguistic rules the software tool was using.

Table 14. A fragment of the list of causes-interactions of Eustachian tube blockage.

Relation-ship or link	Causes or interaction related to Eustachian tube	Source
causing epithelial changes	it was shown that vitamin A deficiency may lead to a tendency **to middle ear infection** by causing epithelial changes in the **eustachian tube** and middle ear.	The role of oxidants and antioxidants in otitis media with effusion in children Taner yilmaz, md, elif gülin koçan, md, h. Tanju besler, phd, gonca yilmaz, md, and bülent gürsel, md, *Otolaryngology–Head and Neck Surgery* *December 2004*
blocks	...and the decrease of the ciliary beat frequency.6 According to Bernstein, there are 3 possibilities leading to the **inflammatory reaction** that **blocks** the **eustachian tube**.	The role of rhinitis in chronic otitis media Olavo mion, phd, md, joao ferreira de mello, jr, phd, md, marcus miranda lessa, md, elder yoshimitsu goto, md, And aroldo miniti, phd, md *Otolaryngology–Head and Neck Surgery* *December 2003*
reduces passive opening pressure	**surfactant** reduces passive opening pressure of the Eustachian tube : comparison study in two animal models,	Intranasal metered dose aerosolized surfactant reduces passive Opening pressure of the Eustachian tube: comparison study in two animal models, S.S. Chandrasekhar, P.E. Connelly, N. Venkatayan, M. El-Sherif Ammar, M. Tabor, A.J. Mautone, *Otol. Neurotol. 23 (January (1)) (2002) 3–7.*

Relation-ship or link	**Causes or interaction related to Eustachian tube**	**Source**
could even affect	**aberration** from normal respiration pattern could even **affect** the **Eustachian tube** and the middle ear, and result in hearing loss [20].	A potential therapeutic method for conductive hearing loss in growing Children-orthodontic expansion treatment Qi-feng Zhang a,b, Jing Guo a,b, Gui-feng Li a,b, Shujuan Zou a,b,*, Zhihe Zhao a,b *Medical Hypotheses 74 (2010) 99–101*
blocks	**Edema** blocks the orifice of the **Eustachian tube** in the nasopharynx as a result of the surgery and the juxta-approximation of the naso-endotracheal tube to the toris tubaris of the Eustachian tube.	Auditory changes in patients Undergoing orthognathic Surgery M. Yaghmaei, A. Ghoujeghi, A. Sadeghinejad, D. Aberoumand, M. Seifi, A. Saffarshahroudi: Auditory changes in patients undergoing orthognathic surgery. *Int.* *J. Oral Maxillofac. Surg. 2009; 38: 1148–1153*
unquestionably produces	demonstrated that **allergic rhinitis** unquestionably produces **eustachian tube blockage** and middle ear underpressures.	Role of allergy in eustachian tube blockage and Otitis media with effusion: A review Joel M. Bernstein, md *Otolaryngology -Head and Neck Surgery* *Volume 114, Number 4 1995*
result in	The overall **effect of viruses** would result in **eustachian tube blockage** with mucus and subse- quent ventilatory or clearance dysfunction.	Role of allergy in eustachian tube blockage and Otitis media with effusion: A review Joel m. Bernstein, md

Relation-ship or link	Causes or interaction related to Eustachian tube	Source
		Otolaryngology -Head and Neck Surgery *Volume 114, Number 4 1995*
caused by	This article will review a model of the pathophysiologyof otitis media and **eustachian tube blockage** caused by **nasal inflammation related to allergy**.	Role of allergy in eustachian tube blockage and Otitis media with effusion: A review Joel m. Bernstein, MD *Otolaryngology -Head and Neck Surgery* *Volume 114, Number 4 1995*
leading to	(...and the decrease of the ciliary beat frequency.6 According to Bernstein, there are 3 possibilities leading to the **inflammatory reaction** that **blocks** the **eustachian tube**.	*The role of rhinitis in chronic otitis media.; Mion, et al. Otolaryngology-Head and Neck surgery Jan 2003*) Bernstein, J,M,

From the list of causes and/or interactions in table 14, it can be seen in the first row that, for instance, *the insufficiency of vitamin* A leads to problems of the Eustachian tube and, therefore, one can assume that there is a plausible connection Cn-Bn-An as the figure 24 shows.

Insufficiency of *Vitamin A* → (affects) → (middle ear) *eustachian tube blockage* → (causes) Ménière disease

Figure 24. Connection between vitamin A and Ménière's disease.

The author has not found within the mined Elsevier literature of Meniere's disease, any citation of *vitamin A* and *Meniere disease,* and there is not even a direct link between vitamin A and the term Meniere disease, although there was some evidence recommending *vitamin B12* and *curcumin*.

A second interesting connection was in row six of table 14, where it states that a cause of Eustachian tube blockage is rhinitis (Berstein 1995). In this case, it was not an element performing an action on the *Eustachian tube blockage* but a cause; therefore, it is a cause's cause of Meniere disease.

Therefore, any approach to overcome *the rhinitis* problem, can be a potential solution to treat Ménière disease.

The author tried to look for other possible solutions using the default mined patent literature. The patent literature is more prone to propose solutions and approaches instead of causes or symptoms, as in medical research papers; therefore, it has been possible to retrieve a list of concepts able to perform some action on the *Eustachian tube blockage.* A selection of that list is shown in figure 25.

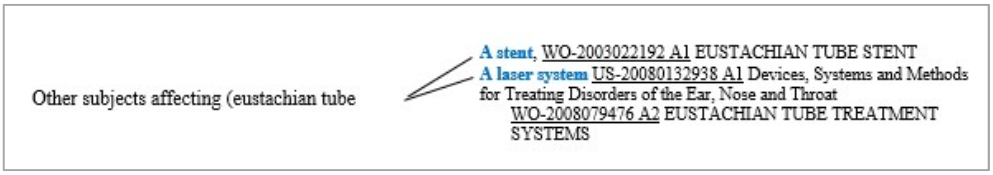

Figure 25

Another application example could be selecting another cause or Bn from the list of table 13 e.g. '*hydrops in the endolymphatic sac*'. Alternatively, to the first example, then the next task could be first to perform a search with the term 'endolymphatic sac' and its synonyms and MESH terms associated., Secondly, to analyze the retrieved full articles and then to find 'systems' or concepts or 'Cn', able to perform some effect on Bn or to be a cause of it. The author wants to stress again that not every relationship or SAO is a valid effect, cause or interacting element, especially in the medical literature. Only by analyzing the cause, effect or interaction relationship in detail and the surrounding context from which it is extracted, one can see the logic link and logic sense. Logically, a seasoned expert will need to validate all the identified relationships as in classical LBD.

After mining the group of articles related to *endolymphatic duct*, an extract of the list of causes or interactions is shown in table 15:

Table 15. fragment of the list of causes-interactions of the phenomenon *hydrops.*

Relationship or link	Hydrops'causes	Source
caused by	To evaluate neurodevelopmental status of children treated with intrauterine red blood cell and platelet transfusion for fetal **hydrops** caused by **parvovirus** B19.	Obstet Gynecol 2007 Jan;109(1):42-7. Long-term outcome after fetal transfusion for hydrops associated with parvovirus B19 infection. Nagel HT, de Haan TR, Vandenbussche FP, Oepkes D, Walther FJ
caused by	During the past two decades, interest in ECoG has again increased because of innovations in recording technique in patients with perilymphatic fistula or endolymphatic **hydrops** caused by Meniere **'s disease**.	Electrocochleography in retrosigmoid vestibular nerve section for intractable vertigo caused by Meniere's disease Wesley w. O. Krueger, md, and ian s. Storper, md, San Antonio, Texas, and New York, New York
Is primarily due to	These results suggest that **hydrops** is primarily due to **blockage of** the **endolymphatic duct** and sac and that degeneration of sensory cells occurs when *blood flow* in the vestibular aqueduct is impeded.	Ann Otol Rhinol Laryngol.1995 Feb;104(2):155-60. Degeneration of vestibular sensory cells caused by ablation of the vestibular aqueduct in the gerbil ear. Kimura RS, Trehey JA, Hutta J.

It should be noted that row two in table 15 shows the still unclear role of hydrops in Meniere's disease, being either a cause or effect as it is already shown in the last row of table 13.

From the last row in table 15, row three, the next step is to find systems affecting the blockage of the *endolymphatic duct,* and from the context, the *blood flow in the vestibular aqueduct* can be a cause's cause.

Blood flow → (affects) → *endolymphatic duct blockage* → (causes) Ménière disease

Figure 26. A chain of causes connects Ménière disease and blood flow.

Returning to figure 21, fish oil, L-carnitine, niacin, acupuncture, etc., are an example of well-known solutions to improve blood flow. They can potentially influence blood flow and hence influence Meniere's disease. Such fact does not mean that blood flow solely can cure Meniere's disease. It has several parallel causes which still need further research.

In this case to prove that the findings are correct, although not new or despite not being combined with other agents (Kostoff 2008), Kumar et al. (2009), mention the use of Coenzyme Q10, CoQ10, to treat several *Meniere's like syndromes*. A good source of CoQ10 is the fish oil. However other substances able to effect blood flow also could be identified and possibly not mentioned in the Meniere or endolymphatic duct literature.

More literature and more related terms should be analyzed to claim for a true discovery (Kostoff, 2008); however, it is not the actual purpose of the present work. The author now tried to proof that the S-S semantic TRIZ can emerge the logic links between the key terms, allowing the researcher to realize the concepts connection immediately, leading to a possible discovery. Therefore, the classic process of LBD continues to be the logical procedure; however, some steps, i.e. in the identification of links, S-S TRIZ can help saving time and trials, helping to reduce the time needed for all the LBD process.

Lithium-Air Battery Systems

By finding current problems and limitations to the existing batteries, as terms An in the sense of literature based discovery, then the task will be to find the Bn terms as causes or systems providing such effect. The final and subsequent step is to find solutions Cn able to perform the correct effect or action on such Bn and, therefore, to the corresponding An. This case focuses on the current problems related to the main function of the batteries (a system) and to its main principle. This principle is the oxygen diffusion in the electrode, to exchange electrons and thus to deploy the current, the battery design intent (Song et al. 2011).

Some current problems are listed in table 16 from the mined patents as well as a cited review article (Song et al. 2011)

Table 16. Selected problems of the Li-Air systems extracted from different published sources.

Some current problems
The conventional lithium secondary **batteries** frequently have the **problems of internal short -circuiting due to formation of lithium dendrites**, and it is difficult to control the formation, particularly in a system using the organic electrolyte solution.
Oxygen transport for the O2 breathing electrode of the Li-Air battery
However, the **inherent solubility of LiOH** is low (12.8 g/100 g H2O at room temperature), which is the drawback of this kind of lithium-air **battery** including LISICON

As an example, one of the Bn terms extracted as causes of the An problem *oxygen transport* is the *tortuosity* and *porosity* of the electrode material. It is interesting to note that some conflict in the TRIZ sense of contradiction appears: if we increase the porosity to improve the oxygen transport then the overall electrode surface is reduced and then, the electron transport is also reduced. However, it is not the purpose in the present paper to solve TRIZ typical conflicts but to perform literature based discoveries faster with the help of S-S TRIZ. In this sense, some Cn elements found in other patents different from the mined group of patents were:

Table 17. Some Cn terms extracted from other patents, which are not related to lithium air batteries, even to batteries at all.

1.addition of metal oxide Moreover, **addition of the metal oxide** in the described manner apparently **increases the macroporosity** and total pore volume of the activated carbon.	EP-2289609 A1Method for making activated carbon for odor control
The thermal activation process **greatly increases the pore volume** and surface area of the carbon particles **by elimination of volatile pyrolysis** products and from carbonaceous burn-off.	US-5769933Activated carbon foundry sand additives and method of casting metal for reduced VOC emissions EP-0813921 A1Foundry sand additive and method of casting metal

There were other Cn terms or solutions connected to the Bn term *porosity* or *pore volume* mentioned in the lithium-air battery patent literature mined, although those shown in table 17 could be considered as not known potential solutions.

In the sense of Day and Shoemaker (2004), the search for the periphery can be accelerated in some of the steps, due to the concept of system in TRIZ and its surrounding as supersystems which are functionally related. With the help of TRIZ based S-S the look for related supersystems and the logic connections between them can be more logic. With the help of syntactics and semantics, it could be also faster and possibly with less need of expert involvement at the beginning of the whole LBD process.

Conclusion

More sources and more coverage can be utilized to ascertain novelty in the concepts, in the sense of new to the state of the art in science as it is known in the patent applications. However, the purpose of the present paper has been to show that with the help of the TRIZ based syntactic-semantic and natural language processing, some steps of the literature based discovery process, can be accelerated with more accurate assessments for logic evidences. The advancement of NLP with the aid of semantic TRIZ, either the assessment of the technological evolvement or the literature based science discovery can be accelerated in some of its steps.

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Chapter 8
By combining techmining and semantic TRIZ the health industry can assess the trends in prostate cancer

A transversal access to knowledge in the process of medical research: diagnosis and biomarkers applied to prostate cancer.

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Abstract

In today's global landscape, innovation is crucial to the competitiveness of organizations. Thus, also medical centers should be aware of advances in new technologies for the treatment of diseases. However, widespread climate of lack of private and government funding coupled with increasing explosion of medical scientific research, reveal the complexity in identifying and adopting strategies effective in managing innovation. This paper presents an approach based on the type "computational linguistics" tools and CAI (computer-aided innovation). It is shown that, through computer programs "Techmining" as VantagePoint, and semantic Triz as GoldFire, National Institute of Oncology Colombia, fast and with so few resources, identified detection systems and most promising monitoring, groups participating researchers and its partnerships related to the diagnosis and prognosis of prostate cancer research.

Keywords: Techmining; Semantic Triz; Competitive Intelligence; Prostate Cancer. 2

Introduction

The prostate cancer is one of the two most common type of cancers in men. In Colombia, prostate cancer is the second cause of mortality in cancer deaths among men. [1]. The Prostate-Specific Antigen (PSA) test, rectal examination, biopsies and transrectal ultrasounds are te4chniques used for early detection. During the last 20 years, the PSA technique has been considered as the best test, however is recognized that such antigen can show higher values in cases other than prostate cancer, such as (BHP) Benign Hyperplasia or prostatitis which can be confirmed only with a biopsy. Such not necessary biopsies can cause distress or anxiety to the patient and raise cost for the public Health. An additional difficulty is about patients with a PSA score between 2 and 4ng/ml, 25% of them could suffer prostate cancer. Some authors highlight that free PSA in serum can better predict the difference between BHP and prostate cancer, as can be seen in figure 27 [2]. Among the new diagnostic methods, there is a urine non-invasive test which detects the gene PCA3 (Prostate cancer antigen 3)). According to different research results, PCA3 can predict the need for biopsy with more precision than the PSA test and can reduce the false positives. In parallel, there are other emerging biomarkers which are being tested in the detection or prognosis, relapse, of the prostate cancer. However, there is a way to be explored [3]. Cancer research centers are exploring and searching less invasive test, less costly and moreover, with more specificity and able to discriminate better. For that purpose, they search for information under the guidelines of the centers, they use collaboration and search in scientific literature given the mounting research activity. The multiplication of thematic congresses and the amount of available scientific literature, requires more and more time and more researchers to find new trends. This is a difficulty and increase the cost of researching.

The present work shows a topic of interest for research centers interested in cancer research. An example of this is the Instituto Nacional de Cancerologia da Colombia, in Bogotá. This Institute is interested in researching the promising biomarker PCA3 as well as other biomarkers and diagnosing enabling Technologies. Here the authors show, that by using the combined approaches of text mining (techmining) supported by the software VantagePoint, and, with the semantic TRIZ approach supported by the software tool Goldfire, the research time can be shorter and withe less difficulties. With the combined approach researchers can learn and research the different alternatives, their apprenticeship curve as well as advantages and disadvantages. This type of information could help research centers and hospitals to take decisions with less risk and better evaluation of expenditures and with less people involved.

The software Goldfire and VantagePoint. Goldfire is a semantic tool capable of reading and understanding full unstructured text in papers. It is inspired in the TRIZ method (Russian acronym for theory of Inventive problem solving), developed from the analysis of thousands of patents to explain the patterns of invention and of technology evolution. Every group of terms can be considered as a system and so it can extract and understand its functional purpose. [4].

The method techmining, helped by the tool software VantagePoint, mines text (scientific articles and patents) to analyze the patterns and contents. As VantagePoint allow us to read information with the software, we can analyze much more information compared to what we could absorb with traditional methods [5].

About Biomarkers

It is known that the prostate specific antigen PSA have some weaknesses as a biomarker. It cannot distinguish enough between cancer and BHP or among aggressive and non-aggressive cancer, leading to usually excessive treatments and unnecessary biopsies. There is a need to find alternative. It is necessary to search for alternatives for testing and monitoring of prostate cancer. The fact that the use of PCA3 as a biomarker was approved by the FDA (Food and Drug Administration) from the U.S. in February 2012, usually combined with the urinary TMPRSS2-ERG, has to be considered. Moreover, the literature shows a preference for, besides the PCA3, to its combination TMPRSS2, a specific membrane antigen PSMA, the antigen cellular-core PSCA, or the nascent prostatic cancer antigen EPCA, and of the activator of the uroquinase plasminogen (u-PA) [6] ,[7], [8]. Some researchers cite Micro RNA (miRNA) as a promising field yet still incipient, needing more research and detection patterns. [9].

Methodology

The Research and queries where performed against databases as Medline Pubmed, Elsevier Science Direct, Springer Verlag, arxiv.org, etc., as well as in international patent databases. In particular, in the database PubMed-Medline and using the query described in the annex to obtain 79.704 records. The records where extracted in full format, downloaded and imported into the software Vantage Point for improving the processing of abstracts, mesh terms, titles and multi-term expressions. The volume of terms reached 1276818 different items. Other sources as the complete collection of PubMed, articles of ScienceDirect, arxiv.org, patents and other sites as research.uk.org cancer and trials.gov clinical, where semantically indexed in order to obtain methods, trends as well as direct answers to questions in natural language using the software IHS Goldfire.

Results

Figure 28 shows the general annual distribution of articles citing the different biomarkers based in more than 79 thousand records from PubMed focused in the diagnosis, detection, monitoring or management of prostate cancer. The result of the analysis shows the expected dominance of the PSA above any other biomarker, despite its controversy. It is worth to remark that the markers PSA and its derivatives as PSMA, etc., and PCA3are prostate specific. The rest of biomarkers are not prostate specific and are also used for other types of cancer. [10]. Meanwhile these other biomarkers when shown in figure 28 are related to prostate cancer.

A magnified detail of the rest of biomarkers in figure 29, show that the PCA3 is one of the techniques more and more used in clinical practice, and in combination with another biomarker TMPRSS2. According to different authors, the aforementioned combination, offer a good specificity and selectivity for the diagnosis of positive cases but also in false-positive cases without ignoring false negative cases. [11]. In next paragraphs, we are going to verify that imaging techniques are introducing even more specificity to the prostate cancer diagnosis. In figure 29, it can be seen that phosphatase of the prostatic acid (PAP) is a well-researched biomarker, whereas PCA3 is more recent with a Strong increase yet not very noticeable. [12]. It can also be noticed the presence of the biomarker IL-6 (interleukin-6), typically used in the prognosis of castrate-resistant prostate cancer [13]. In a moment, an analysis of the different mounting curves was done. It allowed to determine if the emergence of the biomarkers was singular or moved along the inertia of all the increase in literature.

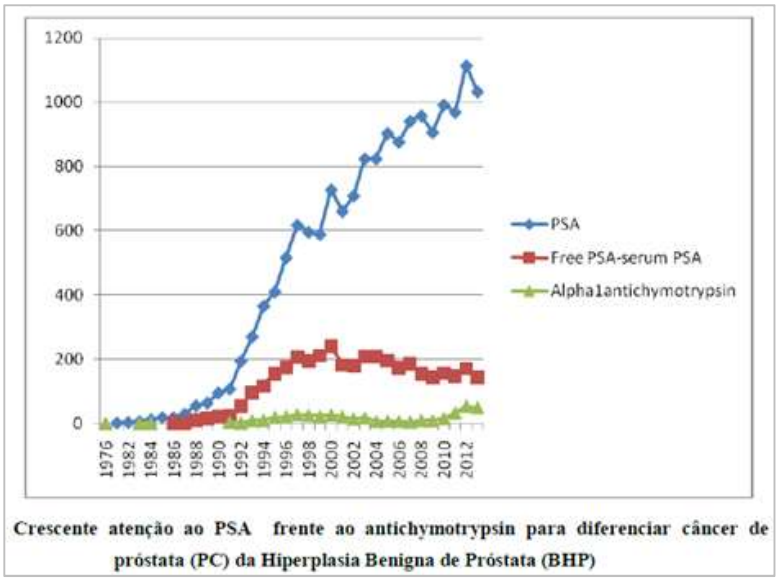

Figure 27. increased attention to the PSA against antichymotrypsin for differentiating prostate cancer from prostate benign hyperplasia.

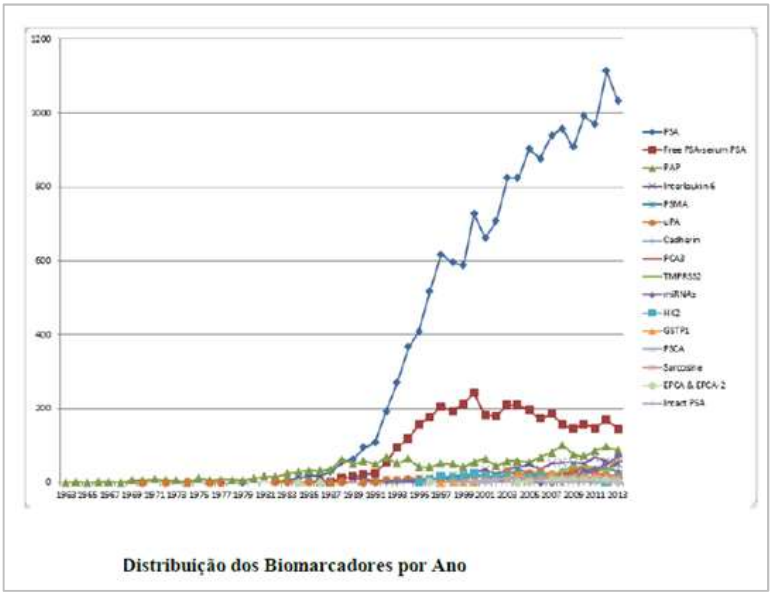

Figure 28. Distribution of biomarkers by year.

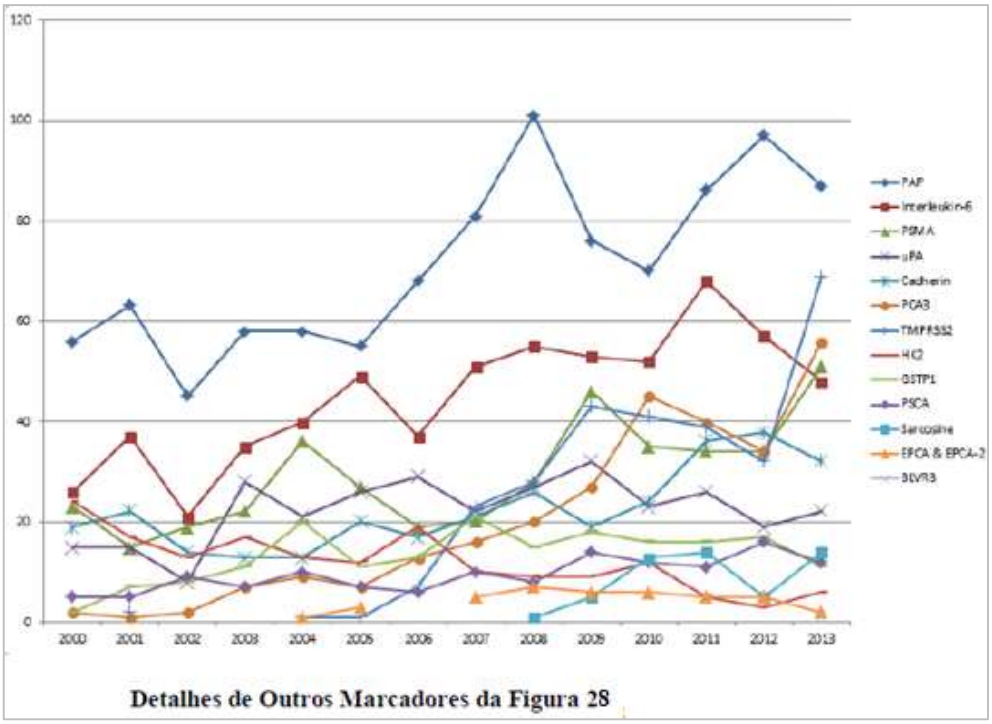

Figure 29. Details about other biomarkers from figure 28.

In the case of patent applications, table 18 shows the companies or institutions which deploy activity in PCA3, given by the fact that the term appears in the claims of the patents.

Table 18. Companies or institutions which deploy activity in PCA3.

Empresas que mais Trabalham com o PCA3

DEPOSITANTE	No. DE PATENTES	TENDÊNCIA DE ATIVIDADE
DiagnoCure, Inc.	17	Aceleração entre 2004 e 2014
StichtingKatholiekeUniversiteit University Medical Center Nijmegen	11	Declínio entre 2009 e 2013
The Johns Hopkins University	8	Declínio entre 2006 e 2014
Gen - Probe Inc.	5	Aceleração entre 2012 e 2013
FUNDACIÓ Institute DE RECERCA HOSPITAL UNIVERSITARI VALL D &apos HEBRON, FUNDACIÓ PRIVADA	4	Declínio entre 2012 e 2013
The Regents of the University of Michigan	4	Aceleração entre 2008 e 2013

It is interesting to observe in table 19 the emergence of new techniques for detecting prostate cancer, specially the immunological imaging methods. Starting from the term 'prostate cancer' semantic TRIZ can extract the methods for detecting the cancer.

Table 19. Methods for detecting prostate cancer, extracted from mining patent claims.

METHOD	EXAMPLE OF CITATION	No. CO-OCCURRENCES
Immunological imaging method	In addition, immunological imaging methods capable of detecting prostate cancer and other cancers expressing 213P1F11 are also provided by the invention, including but not limited to radioscintigraphic imaging methods using labeled 213P1F11 antibodies. U.S. Granted Patents**:** Nucleic acid and corresponding protein entitled 213P1F11 useful in treatment and detection of cancer.	462

METHOD	EXAMPLE OF CITATION	No. CO-OCCURRENCES
In vitro method	the invention provides an *in vitro* method of (a) diagnosing prostatic intraepithelial neoplasia (PIN) or prostate cancer (PRC) or a predisposition to PIN or PRC in a patient, (b) monitoring a course of treatment for PIN or PRC in a patient, or (c) for prognosing PIN or PRC in a patient	62
Utilization of STEAP polynucleotide	to observe the presence and/or the level of PSA mRNAs in methods of monitoring PSA over expression or the metastasis of prostate cancers, the STEAP-1 polynucleotides described here in can be utilized in the same way to detectSTEAP-1 over expression or the metastasis of prostate and other cancers expressing this gene.	30
measurement of expression of mRNA in tissue sample	In some preferred embodiments, detection of prostate cancer markers (e.g., including but not limited to, those disclosed herein) is detected by measuring the expression of corresponding mRNA in a tissue sample (e.g., prostate tissue). mRNA expression may be measured by...	23
comprising of probe by detection system	For example, a detection system can comprise one or more probes to detect one or more prostate cancer specific biomarkers, such as ACSL3-ETV1, C150RF21- ETV1, FLJ35294-ETV1, HERV-ETV1, TMPRSS2-ERG, TMPRSS2-ETV1/4/5, TMPRSS2-ETV4/5, SLC5A3- ERG, SLC5A3-ETV1, SLC5A3-ETV5...	22
prognosing of prostate cancer	In another aspect, the present invention provides: in vitro methods of diagnosing and/or prognosing prostate cancer, PIN or a predisposition to developing same in a patient.	22
utilization of 161P2F10B polynucleotide	...1190 (2000)) to observe the presence and/or the level of PSA mRNAs in methods of monitoring PSA over expression or the metastasis of prostate cancers, the 161P2F10B polynucleotides described herein can be utilized in the same way to detect 161P2F10B over expression or the...	21

By analyzing patent assignees who cite methods for diagnosing prostate cancer with radio in the description, it could be found imaging methods with scintigraphy, using different antibodies biomarkers. Table 20 shows companies like Agensys Inc., of California (EUA) or Philips, from Netherlands, strongly involved in such activity. The latest imaging gadgets are able to diagnose prostate tumors by analyzing the image without any biopsy or physical sample. The case of Agensys Inc. is of interest because is a subsidiary of the group Stella Pharma with a Colombian subsidiary Tecnoquimica. This is an example on which the National Cancer center from Colombia could benefit of a local provider of advanced biomarkers specific in the prostate cancer.

Table 20. Patent trends.

ASSIGNEES	No. OF PATENTS	ACTIVITY TREND
Agensys, Inc.	115	Atividade acelerada entre 2002 e 2013
The Regents of the University of California	52	Declínio de atividade entre 2001 e 2013
The Regents of the University of Michigan	43	Atividade acelerada entre 2003 e 2013
Koninklijke Philips ElectronicNv	30	Atividade acelerada entre 2006 e 2012
The Johns Hopkins University	23	Atividade acelerada entre 2003 e 2013
Sagres Discovery, Inc.	20	Declínio de atividade entre 2004 e 2010
DiaDexus, Inc.	18	Declínio de atividade entre 2002 e 2012
Board Regents The University of Texas System	17	Atividade acelerada entre 2002 e 2013
Phigenix, Inc.	16	Declínio de atividade entre 2010 e 2013
OncotherapyScience, Inc.	14	Atividade acelerada entre 2005 e 2013
Millennium Pharmaceuticals, Inc.	13	Declínio de atividade entre 2002 e 2010

The growing use of imaging methods for detection and monitoring of prostate cancer, include the use of choline, a precursor of the phosphatidylcholine, a necessary phospholipid for the synthesis of the molecular membrane, being the later a marker of the cellular proliferation. It can be used either as imaging marker or as activity biomarker. [14]. Figure 30 shows the increasing presence of choline in the extracted records about prostate cancer detection.

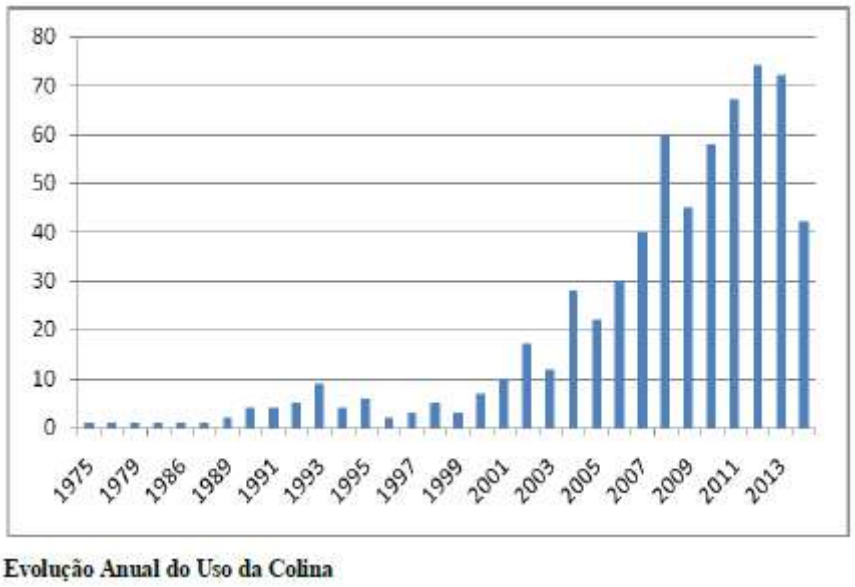

Figure 30. Evolution of the use of choline.

By using the approach of semantic TRIZ to the cited databases, the authors could extract the different applications of choline, e.g. by asking "what is choline used for?"

The answers show 20 citations of choline, as the advanced monitoring of prostate cancer by using F18 choline in PET/CT, that is, a positron emission tomography coupled with a scanner tomography and its application to bone metastasis, extracted from different sources. It was also possible to see the correlations between the techniques of imaging, choline, digital rectal exam (DRE) and transrectal ultrasound (TRUS) within the indexation of 20 thousands research articles (26 % of the total group of records extracted from PubMed) from a total of 79 thousands. As a logical consequence, DRE, TRUS and RMI are more oriented to the initial diagnosis whereas PET/CT – choline more to advanced stages of the disease, as presented in table 21.

Table 21. Citations of applications of choline.

ANSWER	CITATION	DOCUMENT TITLE	SOURCE
assessment of bone metastasis in prostate cancer	The use of F-18 choline PET in the assessment of bone metastases in prostate cancer: correlation with morphological changes on CT.	Prostate Cancer: A Comprehensive Perspective	2013 Springer book Prostate Cancer: A Comprehensive Perspective Editors: AshutoshTewari ISBN: 978-1-4471-2863-2 (Print) 978-1-4471-2864-9 (Online)
assessment of bone metastasis in prostate cancer	[35] M. Beheshti, R. Vali, P. Waldenberger et al., "The use ofF-18 choline PET in the assessment of bone metastases in prostate cancer: correlation with morphological changes on CT," Molecular Imaging and Biology, vol.	Lymph Node Staging with Choline PET/CT in Patients with Prostate Cancer: A Review	Lymph Node Staging with Choline PET/CT in Patients with Prostate Cancer: A Review A. Skanjeti1 and E. Pelosi2 ISRN Oncology; Volume 2011, Article ID 219064, 6 pages doi:10.5402/2011/219064
assessment of bone metastasis in prostate cancer	SeminNucl Med 39(6):396–407Beheshti M, Vali R, Waldenberger P et al (2009b) The use of F-18 choline PET in the assessment vof bone metastases ini prostate cancer: correlation with morphological changes on CT.	Radionuclide and Hybrid Bone Imaging	2012 Springer book Radionuclide and Hybrid Bone Imaging Editors: I. Fogelman, G. Gnanasegaran, H. van der Wall ISBN: 978-3-642-02399-6
assessment of bone metastasis in prostate cancer	The use of F-18choline PET in the assessment of bone metastases in prostate cancer: correlation with morphological	Role of 11 C-choline PET/CT in the restaging of prostate cancer patients showing a single lesion	Role of 11C-choline PET/CT in the restaging of prostate cancer patients showing a single lesion on bone scintigraphy Fuccio C. et al. ; Annals of Nuclear Medicine; July 2010,

Figure 31 presents relevant correlations between MRSi and MRS (0,354); between PET/CT and colina (0, 421); ebetween DRE and TRUS (0,309).

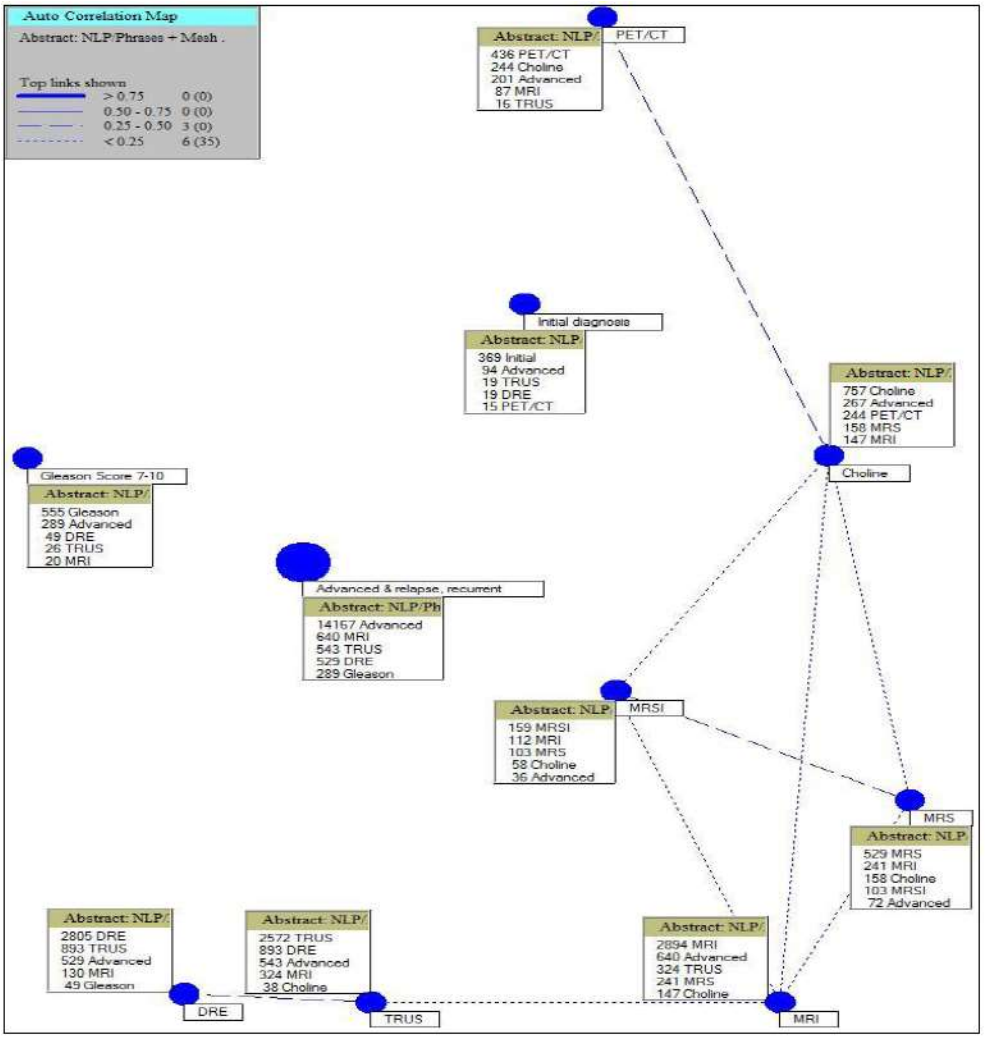

Figure 31. Correlations map of the diagnosing techniques.

The trend of the different technique for diagnosing or prognosing of the prostate cancer can be seen in figure 32, where the nuclear magnetic resonance outstands. Still incipient but outstanding are the new applications of nanoparticles as agent of contrast in the diagnosis and prognosis stages. [15].

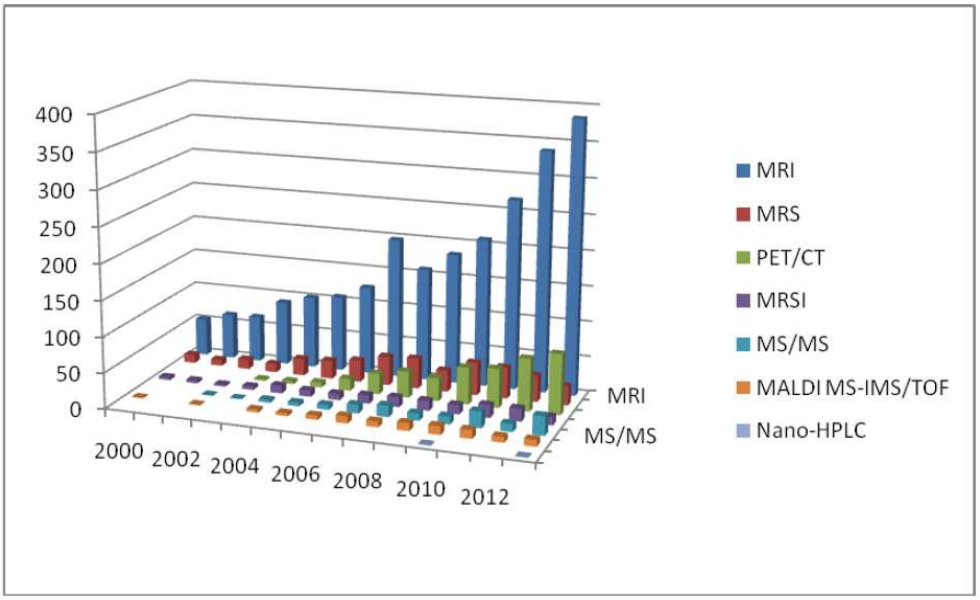

Figure 32. Trends of citation of different prostate cancer diagnosing techniques.

Conclusion

From the analysis of research articles and patents, the authors have observed the increasing use of combinations of biomarkers for improved diagnosis. Also observed is the increasing combination of biomarkers with image analysis techniques and bi-components, emphasizing the strong growth of the magnetic resonance to guide the biopsies and to assess cancer volumes and position of prostate cancer. These two conclusions confirm one of the evolutions patterns of the TRIZ methodology: first biomarkers, then combinations of imaging techniques and different biomarkers. With a reduced dedication of time and people, it was possible to identify some of the possible research lines about biomarkers as well as techniques for the diagnosis of the prostate cancer. Also, it was possible to introduce some examples of key parameters about potential partners. In summary, with the use of a combined approach supported with software tools it is possible to access to new knowledge, in a transversal/horizontal way and to identify trends based on objective evidences applied to medical and health sciences objectively.

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Annex

Next is the query equation at PubMEd in June 2014:

Search query on PubMed June, 9th 2014: Search (((((("prostatic neoplasms"[MeSH Terms] OR ("prostatic"[All Fields] AND "neoplasms"[All Fields]) OR "PCA"[All Fields] OR "prostatic neoplasms"[All Fields] OR ("prostate"[All Fields] AND "cancer"[All Fields]) OR "prostate cancer"[All Fields])))))) AND (((((("biological markers"[MeSH Terms] OR ("biological"[All Fields] AND "markers"[All Fields]) OR "biological markers"[All Fields] OR "marker"[All Fields]) OR ("diagnosis"[MeSH Terms] OR "diagnosis"[All Fields] OR "diagnostic"[All Fields]) OR detection[All Fields] OR "management"[All Fields] OR "prognosis"[All Fields] OR "monitor"[All Fields]OR predict[All Fields])))) As ferramentas utilizadas para o TechMining foram o software Vantage Point e na semântica, o TRIZ e o software GoldFire.

Chapter 9
Can the combination of techmining and semantic TRIZ set advantage in the detection of strategy shifts in a company strategy? A case in probiotics industry

Discovering shifts in competitive strategies in probiotics, accelerated with Techmining

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Abstract

Profiling the technological strategy of different competitors is a key element for the companies in a given industry, as well to technology planners and R&D strategists. The analysis of the patent portfolio of a company as well as its evolution in the time line is of interest for technology analysts and decision makers. However, the need for the participation of experts in the field of a company as well as patent specialists, slows down the process. Bibliometrics and text mining techniques contribute to the interpretation of specialists. The present paper tries to offer a step by step procedure to analyze the technology strategy of several companies through the analysis of their portfolio claims, combined with the use of Techmining complemented with a text mining tool. The procedure, complemented with a semantic TRIZ analysis provides key insights in disclosing the technological analysis of some competitors in the field of probiotics for livestock health. The results show interesting shifts in the key probiotic and prebiotic ingredients for which companies claim protection and therefore offers clues about their technology intention in the life sciences industry in a more dynamic, convenient and simple way.

Introduction

Companies try to maintain its profitability and activities by introducing competitive strategies that differentiate them from other competitors either by introducing new products or services to the market or, by reducing costs (Grant 2006; Porter 2008). Appropriability by means of filing patents of a given new technology is one of the main assets for succeeding in innovation (Teece 1986; Kim et al 2016) Through the application of patents, companies can establish a barrier to competitors which results in a competitive asset (Grant 2006; Porter 2008). Nowadays, patents and other intangible assets form a greater portion of the value of a company (Soranzo et al 2016).

By maintaining a strong patent portfolio, life science companies may secure better funding, increase market value or have a driver for gaining or maintaining the competitive advantage of a company (Rose 2007; Abramson 2011). Therefore, an increasing interest in analyzing patent portfolios helps companies to anticipate competitors' strategies (Wang et al 2009), and to inform decision makers better. Patent analysis help researchers and policy makers to measure innovation strategies, knowledge diffusion, merger and acquisitions, etc. (Parker et al 2013; Grant et al 2014).

There are many examples showing that patenting key technology achievements represent a big barrier for new entrants. In the case of energy harvesting, some key patents and in particular their claims, could control a whole industry (Kume 2010; Niwa 2016) Energy harvesting is the name for technologies capable of collecting minute amounts of energy from the surrounding. Knowledge intensive industries, as molecular biotechnology or nanotechnology, have also a large patenting activity (Grant et al 2014) In particular, the nutraceutical or medical nutrition industry is also a knowledge intensive industry where

patenting is a key element for protecting new products because of a monopoly period of twenty years. (Chih-Hung 2013).

Tracking of patents, patent portfolio analysis and patent landscaping are common strategies to understand the evolution of technologies and the intellectual property strategies of the incumbents, as IP risks and prediction of technology commercialization (Pargaonkar 2016). Patents and intellectual property have moved to the core of the business as we move into a knowledge-based economy (Porter and Cunningham 2005) and into a globalized economy. Most of the patent landscaping work is based on the analysis of fields as title, abstract or citations, and less have concentrated in the claims field. Ferraro et Wanner (2011), and Wang et al (2015) explain about the added difficulty of analyzing claims for a patent landscaping due to the complexity of their linguistic construction. According to Veberne et al. (2010), sentences are longer in claims in relation to normal language, and the syntactic structure and appearance of not common terms make it more difficult to analyze.

There is a need for landscaping patents based on the claims of patents, in a standard and more convenient manner. Traditional text mining patent landscapes which are more focused on trends and foresight try to look for consistent trends in time (Porter et Newman 2011) more than on specific items and their punctual changes in a particular time. Additionally, for the techmining of patent literature purposes, normally due to the extent of full patents, the authors use title and abstracts although recognizing the value of other parts of the patent document (Xie and Miyazaki, 2013; Porter and Cunningham 2005).

The advantage of analyzing claims is twofold. Firstly, it is richer in key terms for the subject of a company and secondly, that terms represent the core elements said company pretends to protect. According to Porter et Cunningham (2005), patent claims contain essential information on the intended purpose of a company. The text in claims is more complete, describing explicitly features in order to provide full legal protection (Noh et al.; 2015).

After the European Union ban of antibiotics as growth promoters (AGP) in animal production, on January 1st 2006 (Animal Task Force 2013), a high interest in alternative methods to improve the performance of livestock has been observed. Furthermore, a significant reduction of antimicrobials as therapeutics has become a principal objective of the EU for the next years. Among the alternative methods there are feed additives with prebiotics and probiotics, phage therapy or bacteriophages, vaccines and mixed probiotics and symbiotic. The latter being a promising alternative (Allen et al 2012).

Probiotics refer to viable microorganisms (bacteria or yeasts) that exhibit a beneficial effect on the health of the host when they are ingested. Prebiotics refer to a non-digestible food ingredient, which are perceived as beneficial to animal health. (Yang *et* Choct, 2009). Symbiotics is a combination of probiotics and prebiotics (Collins et Gibson, 1999; Schrezenmeir et De Vrese, 2001).

The industry of prebiotics and probiotics enter in the feed market and therefore do not follow the long development and test before reaching the market of pharmaceutical companies. This offers a large market opportunity which is being seized with a large patent portfolio (Abramson 2011). However, probiotics are increasingly gaining health applications (Weenen et al 2013), supported by major advances in the identification and characterization of microbes (O'Callaghan et al 2016). Some of these health applications include disbyosis, intestinal diseases of mammals, among others (Foligné et al 2013; Banan-Mwine Daliri et Lee 2015).

The industry of animal health is related to the medical nutrition and therefore it finds itself between the food and the pharmaceutical industry and it represents a fast-growing segment within the health and life sciences. As a growing industry, it is relevant to protect their new development through different intellectual property instruments (Weenen et al 2013). Therefore, despite other parts of the patent document could bring a richer description of scope, the protection companies try to accomplish should be clearly stated in the claims of their patents. Visualizing changes in what companies in that industry protect, by means of tracking the claims of their patents, is an object of the present paper.

The present paper proposes a technique for identifying and visualizing changes in the technology strategy of different companies, faster and with less expert involvement by using techmining complemented afterwards with semantic TRIZ. For testing the technique, we have applied the procedure in the industry of animal health and more particularly to the industry of prebiotics and probiotics for modulating the microbiome and its application to gut health in livestock and husbandry related animals. The technique of the present paper concentrates on the analysis of the content of patent claims due to their specificity, of at least three competitors in the mentioned sector. The result is then plotted in the timeline to easily detect if there are strategies which are emerging, or decreasing, if new elements enter into the technology and, if there are disruptions in their patenting intent. It is expected that a shift either in the number or the terms used in the claims may involve either a change in technological interest or a change in resources dedicated to a given technology.

More in detail the procedure performs the following five steps. First, to extract by means of natural language processing the terms of the claims of a searched and selected set of patents; Second, removing common, noisy terms via fuzzy matching, manual touch-up, using term grouping and further applying thesaurus grouping as well as some further clustering scripts; Third, to generate a factors map to extract the main terms in which term clumping strategy also contributed taking into account that newest terms (still nascent) could also be critical; Fourth, plotting such terms in a visualization tool which plots number of citations in claims per year e.g. in a Gantt / bubble map , to see the emergence, shifts or disruptions and trends of key terms and classifications; Finally fifth, checking shifts in claim terms being protected and/or comparing the map of different competitors and complementing the explanation of the key observations, with the help of semantic TRIZ answers.

We expect that the proposed claims based patent landscaping complemented with semantic TRIZ, beyond subject-action-object (SAO) based analysis, can be incorporated by companies and technology planers to first quickly detect changes in patent application strategy and to better inform their technical strategy decisions.

The arrangement of this paper performs with the following order. The section Theoretical background presents an overview of scholars' research in the field. The 'Method' section describes the procedure of analyzing claims with the combination of Techmining and Semantic TRIZ. The Case study presents an application of the approach to the emerging field of gut health in livestock as an alternative AGP with the results. The section 'Discussion and Conclusion' discusses the advantages and limitations of the method and outlines future research aspects.

Theoretical background

One of the approaches for studying patent portfolio of a given technology is patent landscaping. Patent maps help to visualize trends and relationships among a group of patents. Patent landscaping can adopt different strategies, including research profiling of patents (Bubela et al. 2013; Grant et al 2014) Patent maps and patent profiling have been object of studies by many researchers and scholars over the last decades (Mogee 1991; Ernst 2001; Chih-Hung 2013; Grant et al 2014; Abbas et al 2014).

Research profiling is one of the five stages in mining external R&D technology (Porter et Newman 2011) Research profiling helps to highlight key outstanding elements. Research profiling uses a modern search engine and text mining tools to characterize large bodies or related literature complemented with the use of Techmining to analyze patent activity of several companies as pattern analyses (Porter et Newman 2011; Porter et Cunningham 2005).

The advent of semantic processing of texts seems to criticize the use of keywords as a valid instrument to extract technology strategies of a company. Although the subject-action-object (SAO) based textual analysis do extract the relationships between words better than just by keywords, such approach is best applied for identifying technological similarities (Park et al 2012; Gerken et Moehrle 2012) competing technologies (Yoon et al 2013) or mergers and acquisitions (Park et al 2013) More specifically, Choi et al (2011), express the limitations of keyword analysis to identify technology trends since keywords cannot express information on how the technology is used or for what purpose. That paper extracts the SAO relationships; however, it needs to establish a network to identify key functions based on the number of action-object (AO) relations. The tools using SAO based extraction are limited since they extract also noisy terms (Abbas et al. 2014).

The present paper tries to overcome the limitations of using keywords, by focusing on one critical field of the patent document: the claims. It is in the claims where

applicants try to protect their technology strategy. Besides, the present paper focuses only on the earliest patent of the INPADOC patent family, which has claim text in English. It is one of the options of the database used. A patent family is a set of patents filed at different patent authorities that refer to the same invention. It is relevant to select only one family member in order to avoid repeated count of terms in the analysis.

We then apply the techmining technique complemented with semantic TRIZ. To better understand the capabilities of each technique, a short definition of each is following. Tech mining helps to identify trends, technology profiling, and semantic TRIZ allows to understand what the elements of such trends are being used for, what are the causes and effects, components and surrounding elements, etc. The advantage of one aspect of semantic TRIZ is the further interpretation of linguistic forms of different SAO's and the use of other processing tools as mereology and anaphora resolution. It goes beyond the extraction of a list of SAO relationships which need to be statistically treated to offer some meaning. The combination of tools answer to most of the key questions, who, when, where, how, why, etc., an expert may ask him/herself when exploring a technology. The second advantage of semantic TRIZ is its view of technology as an ecosystem and so having into account the relationships of a technology with its surrounding elements. (Vicente-Gomila and Palop 2013; Vicente-Gomila 2014).

Tech mining is a discipline involved in applying information tools to count, interrelate and to analyze science and technology information to help to understand changing and emerging technologies. Tech-mining tools help to analyze, validate and qualifies a large amount of data. They can extract trends, relationships, hidden research networks and weak signals from a vast database of scientific articles. Techmining can use co-words analysis, but it also involves the use of technology measures and innovation indicators to help understand the dynamics of the obtained results and its importance to the subject matter analyzed (Porter and Cunningham 2005).

Semantic-TRIZ (Verbitsky 2004) is based on extending the view of systemic functional relationships identified in the TRIZ methodology among the components, features and information related to a technology, with the help of linguistics. Semantic-TRIZ links syntactically and semantically the problem with a solution in a research document or a patent. Implemented in a syntactic-semantic software tool, inspired in the TRIZ methodology, such technology uses linguistic techniques such as mereology, anaphora resolution, cause– effect analysis, applications, failures, properties, etc. to link the functions of a technology, its components and their relationships. It is therefore able to link the knowledge of the user with different – even new– knowledge extracted from documents (Vicente-Gomila and Palop 2013), Techmining uncovers questions as 'what', 'when', where' whereas Semantic TRIZ can add the 'How', 'Why' and 'What for' of a technology being explored. To properly evaluate the strategic technology intent through the patent portfolio, one of the key fields to study is the claims field. It is in the claims where companies define the core invention they pretend to defend of potential competitors

(Tong and Frame 1994). Previous research dealing with claims had focused on counting the number of claims being it independent or dependent, may have not been very reliable as a measure of technology relevance (Lanjouw and Schankerman 1999; The UK patent Office patent guide).

The UK patent office patent guide document shows, as way of example, that the same patent (within a family) can have 133 claims when granted by the European Patent Office but only 7 claims when granted by the USPTO or 26 claims when granted by the Chinese Patent Office. Lee et al (2016) use the number of claims, however they propose a stochastic method to have a more accurate inference.

Tong and Frame (1994) demonstrate that the analysis of patent claims may be a better indicator of technological intent or effort. Also, Yang et Soo (2012) coincide on the relevance of the claims in the patent. He et al (2016) also recognize the suitability of using claims and the fewer studies about patents using them. Therefore, in the latest decade, there is a need to research on using claims as better technology indicators. The fact that a different number of claims could distort the number of terms extracted from text analysis, can be overcome by using only one member of a patent family, the earliest of the INPADOC family and distribute the extracted terms of the claims of each unique member across the timeline. The capacity of techmining for identifying trends implemented through a tech mining tool can process the sentences of the claims with natural language processing, extracting the key terms cited in the sentences. In the case presented in this paper, the prebiotics and probiotics as well as coadjuvants for enhancing their effect are the key terms extracted from the claims. Although independent claims can be broad and general however when descending to the dependent claims, applicants need to mention at any level the key probiotic or combination of probiotic and/or prebiotics to be protected, allowing to be extracted and profiled.

Method

The present paper proposes to perform a landscaping based on a research profiling of the patent portfolio of leading companies in the field of livestock health. Said research profiling had to be centered in analyzing the key terms of each of the patent families identified in the portfolio of those companies. To accomplish that, the authors selected to work with the earliest patent member of the INPADOC family of every patent family. Another relevant aspect of the proposed procedure is to focus the analysis in the claims of each patent family. It is in the claims where an applicant discloses the key elements of the technology to be protected. The terms used in claims are key for understanding the strategy in a patent and therefore the technological intent of the applicant.

The research profiling of claims implies analyzing the keywords mentioned in such field of the patent documents either in the first independent claim or in any of the further following claims. Identifying the key terms in the claims and plotting such terms against time allows to understand the trend in key elements, probiotics and prebiotics in the present paper. The monitoring of such strategy for every company in timeline, gives a good perspective for competitors to detect shifts and special movements of the target company.

The advantage of analyzing claims is double. On one hand, it is richer in key terms for a company and second hand, that terms represent the core elements the company pretends to protect. The table 22 shows a sample record of a patent from the portfolio of one of the analyzed companies. As can be seen on table 22, neither the title nor the abstract cite all the terms as in the claims. Even the 'Derwent title' which is human composed, cannot be as rich in terms and contents as the claims. By using Techmining and processing through NLP terms, all the terms in the claims, a richer group of terms can be extracted which are core to the strategy of a company. On the table, it can be seen that the Derwent title mentions *N-acetylated oligosaccharide,* and *sialylated oligosaccharide* as key prebiotic terms, whereas the abstract mentions the two terms as well and further mentions a generic probiotic without any specificity.

The claims however, do mention a higher in hierarchy i.e. a hypernym term of the family 'fructo' and 'oligo' for the oligosaccharides mentioned above, and further mention the addition of *arachidonic acid ARA* and *docosahexanoid acid DHA*. Finally, claims further specify the type of probiotic used, *lactobacillus reuteri* or *rhamnosus*, as well as the specific sialylated oligosaccharide: *3'-sialyllactose or 6'-sialyllactose,* and the neutral oligosaccharide *lacto-N-tetraose* in the cited example.

Therefore, it seems clear that the NLP processing of claims can enrich the analysis as compared to title and abstract only analysis and it also can be more specific as more specific terms appear. It is evident that by analyzing the description of the patent, the same type of terms as in claims can appear, however analyzing the full text would include a large quantity of void and jargon type terms. The description part has a more detailed explanation of the functioning of the technologies involved and about the appearance of

the invention (Noh et al. 2015) Nevertheless, the terms appearing in the claims are the core of the protection companies try to pursue in the market space.

Table 22. Extract sample of the claims from one patent of the retrieved set.

Publication number	WO2013057062A120130425 Record 210/1993
Patent Assignee	NESTEC S.A., CH
Title	COMPOSITION FOR USE IN THE PROMOTION OF INTESTINAL ANGIOGENESIS AND OF NUTRIENT ABSORPTION AND OF ENTERAL FEEDING TOLERANCE AND/OR IN THE PREVENTION AND/OR TREATMENT OF INTESTINAL INFLAMMATION AND/OR IN THE RECOVERY AFTER INTESTINAL INJURY AND SURGERY
Title Derwent	Composition used e.g. as supplement, and to treat intestinal inflammation, comprises *long chain polyunsaturated fatty acid*, *probiotic* and mixture of oligosaccharides (having e.g. *N-acetylated oligosaccharide* and *sialylated oligosaccharide*).
Abstract	The invention discloses a composition comprising at least one *long chain polyunsaturated fatty acid*, at least one probiotic and a mixture of oligosaccharides, said mixture containing at least one N-acetylated oligosaccharide, at least one *sialylated oligosaccharide* and at least one *neutral oligosaccharide*, for use in the promotion of intestinal angiogenesis and of nutrient absorption and of enteral feeding tolerance- and/or in the *prevention and/or treatment of intestinal inflammation, such as necrotizing enterocolis, and/or in the recovery after intestinal injury and/or surgery.*
Some initial claims	A composition comprising at least one long chain polyunsaturated fatty acid (LC-PUFA), at least one probiotic and a mixture of oligosaccharides, said mixture containing at least one N-acetylated oligosaccharide, at least one sialylated oligosaccharide and at least one neutral oligosaccharide, for use in the promotion of intestinal angiogenesis and of nutrient absorption and of enteral feeding tolerance and/or in the prevention and/or treatment of intestinal inflammation, such as necrotizing enterocolitis, and/or in the recovery after intestinal injury and/or surgery.

	A composition according to the preceding claim, wherein the neutral oligosaccharide is chosen among *fructooligosaccharides (FOS)* and/or *galactooligosaccharides (GOS)*, preferably GOS. A composition according to any one of the preceding claims, wherein said oligosaccharide mixture contains at least one N-acetylated oligosaccharide selected from the group comprising GalNAcal ,3Gal31 ,4Glc (=3'GalNAc-lac = N-acetyl-galactosaminyl-lactose), Gal31,6GalNAca1,3Gal3"l,4Glc (= 6'Gal- 3GalNAc-lac = galactosyl-N-acetyl-galactosaminyl-lactose),.. A composition according to any one of the preceding claims, wherein the oligosaccharide mixture is present in an amount of 0.5-70%, more preferably 1 - 20%, even more preferably 2-5%, with respect to the total weight of the composition. A composition according to any one of the preceding claims, wherein the LC- PU FA is chosen among *arachidonic acid (ARA)* and *docosahexanoic acid (DHA)*, preferably the *LC-PUFA* is a mixture of ARA and DHA. A composition according to any one of the preceding claims, wherein the probiotic is chosen among probiotic bacterial strains, preferably the probiotic is a lactobacillus o r a bifidobacterium, more *preferably the probiotic is Lactobacillus rhamnosus*, *Bifidobacterium lactis* and *Lactobacillus reuteri*. A composition according to any one of the preceding claims, wherein the N acetylated oligosaccharide is selected from the group comprising lacto-N neotetraose (or LNnT) and *lacto-N-tetraose* (or LNT). 9. A composition according to any one of the preceding claims, wherein the sialylated oligosaccharide is selected from the group comprising *3'-sialyllactose* and *6'-sialyllactose*, and preferably the sialylated oligosaccharide comprises both 3'-sialyllactose and 6'-sialyllactose, the ratio between 3'-sialyllactose and 6'-sialyllactose lying preferably in the range between 5:1 and 1 :2.

The procedure proposed in the present paper takes advantage of the natural language processing capabilities of the techmining tool of Search Technology. The analysis performed by natural language processing, could extract and correlate the key elements of their technology, disclosed in both, the independent claims and the dependent ones. Further analysis of the 1993 patent families with the help of a semantic TRIZ tool, extracted the meaning of any term appearing in the claim, by offering ‘applications’, ‘properties’ and definitions’ among other typical questions for said term.

In the present paper, the use of claims limits somehow the scope of the semantic extraction since the sentences of the claims are detailed for systemic purpose of affiliation and features, but less for the functioning of the invention. Therefore, to extract the application or uses of the prebiotic and probiotic terms also the description of the patents have been analyzed. This fact does not change the scope of the paper but further reinforces the procedure proposed. The shifts in strategy are analyzed by tech mining, but to further understand the relevance and the context of the terms involved in the shifts of interest, the description of the same set of patents is also semantically analyzed. (Abbas et al. 2014).

The proposed framework consists first in performing a comprehensive search in any existing database using all the keywords and the synonyms and, in the case of animal health, the stemming words of each prebiotic and probiotic class. Grouping the result of the search in patent families and selecting, according to any logic criteria one member of each family to avoid repetition in the number of terms protected by each company. Any patent member in the families, despite of the number of claims, share at least the key elements they want to protect and therefore the key terms mentioning such elements. The next step is to import the results in text mining tool specially inspired in the knowledge of technology management e.g. techmining. By means of cleaning and grouping different variations of probiotic and prebiotic terms, the preparation of the further analysis using different thesauri and using tools as cluster suite script in the techmining tool, techmining tool to remove irrelevant and stop terms.

Next is comparing companies' portfolio by listing applicants and selecting those with a steady activity in the latest 5 years. A key step for advancing strategy analysis is by first grouping elements cited in the claims that act as 'subjects' and also grouping elements which may be considered as 'targets' of functions performed by the subjects. Then, a co-occurrence matrix crossing subjects with targets brings an initial clear view of '*who'* is dedicated to '*what'* and what ingredients are targeted to which type of animals as shown in figure 33. The penultimate step is to plot the evolution of different key elements of said claims in time by using, for instance, a bubble chart which shows the number of patents citing any key term distributed by years. It shows the frequency and distribution against time, of the different terms to see which are emerging, which are decreasing or, if there is some disruption in the intent of any company.

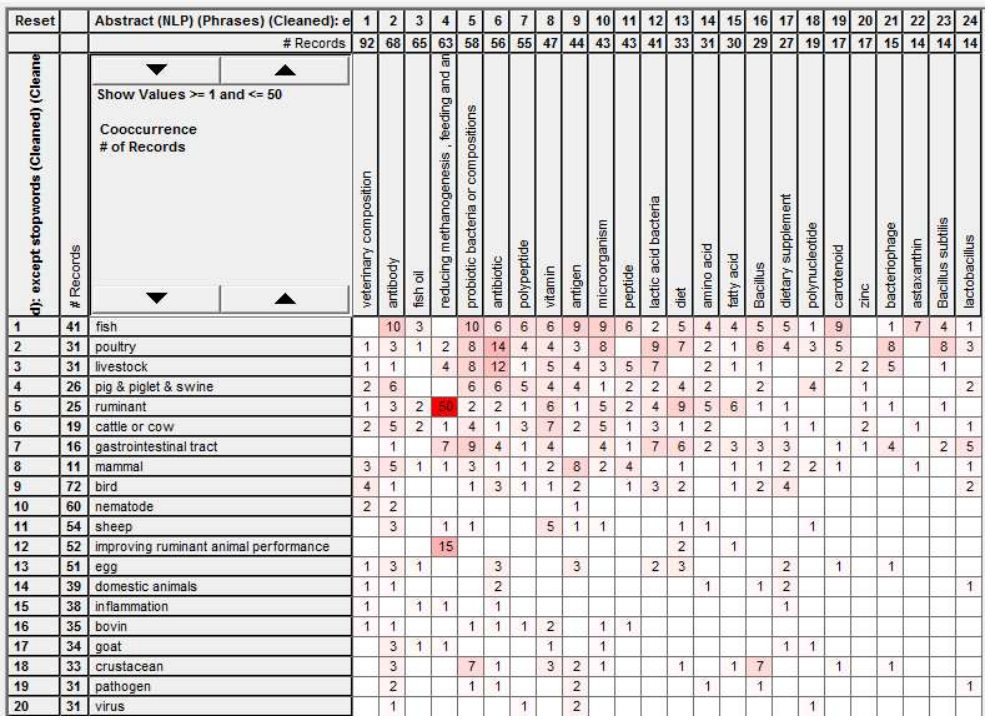
Finally, to understand the purpose of different companies in citing key terms in time, the semantic TRIZ tool can bring information about how a term is used, or how is it obtained or what is it part of other components (mereology), or what are the properties exhibited by said term.

The process is summarized in table 23.

Table 23. Steps for detecting shifts in company strategies.

1. A search in in a patent database brought 1993 patent families
2. NLP processing and extraction of claims terms
3. Removing common, noisy terms via fuzzy matching and cluster suite script, both in VP and manual touch up. Using the thesaurus grouping
4. Extracting terms with a factors map and further selecting with the help of experts from IRTA
5. Establishing a relationship of subjects and objects and cross correlating them with the help of the co-occurrence matrix
6. Going further the comparison of terms but also adding the dynamics of such terms against its distribution in time to see the dynamics of key elements in the claims and, to see the shifts and changes in time
7. Take advantage of semantic processing to add meaning about the uses and properties of any of the components in the claims

Figure 33 shows an example of step 5 in the table, using a co-occurrence matrix crossing the subjects, e.g. probiotics, prebiotics, or special food ingredients as fish oil, in the present paper and targets, e.g. animals or a specific part or aspect of an animal or a pathogen present in livestock animals. Such co-occurrence establishes a SAO relationship based on techmining with statistically relevance, therefore outperforming some of the limitations of the traditional SAO analysis.



Reset		Abstract (NLP) (Phrases) (Cleaned): e	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
		# Records	92	68	65	63	58	56	55	47	44	43	43	41	33	31	30	29	27	19	17	17	15	14	14	14
d): except stopwords (Cleaned) (Cleane	# Records	Show Values >= 1 and <= 50 Cooccurrence # of Records	veterinary composition	antibody	fish oil	reducing methanogenesis , feeding and an	probiotic bacteria or compositions	antibiotic	polypeptide	vitamin	antigen	microorganism	peptide	lactic acid bacteria	diet	amino acid	fatty acid	Bacillus	dietary supplement	polynucleotide	carotenoid	zinc	bacteriophage	astaxanthin	Bacillus subtilis	lactobacillus
1	41	fish		10	3		10	6	6	6	9	9	6	2	5	4	4	5	5	1	9		1	7	4	1
2	31	poultry	1	3	1	2	8	14	4	4	3	8		9	7	2	1	6	4	3	5		8		8	3
3	31	livestock	1	1		4	8	12	1	5	4	3	5	7		2	1	1			2	2	5		1	
4	26	pig & piglet & swine	2	6			6	6	5	4	4	1	2	2	4	2		2		4		1				2
5	25	ruminant	1	3	2	50	2	2	1	6	1	5	2	4	9	5	6	1	1			1	1		1	
6	19	cattle or cow	2	5	2	1	4	1	3	7	2	5	1	3	1	2			1	1		2		1		1
7	16	gastrointestinal tract		1		7	9	4	1	4		4	1	7	6	2	3	3	3		1	1	4		2	5
8	11	mammal	3	5	1	1	3	1	1	2	8	2	4		1		1	1	2	2	1			1		1
9	72	bird	4	1			1	3	1	1	2		1	3	2		1	2	4							2
10	60	nematode	2	2							1															
11	54	sheep		3		1	1			5	1	1			1	1				1						
12	52	improving ruminant animal performance				15									2		1									
13	51	egg	1	3	1			3			3			2	3				2		1		1			
14	39	domestic animals	1	1				2								1		1	2							1
15	38	inflammation	1		1	1		1											1							
16	35	bovin	1	1			1	1	1	2		1	1													
17	34	goat		3	1	1				1		1							1	1						
18	33	crustacean		3			7	1		3	2	1			1		1	7			1		1			
19	31	pathogen		2			1	1			2					1		1								1
20	31	virus		1					1		2									1						

Figure 33. Example of co-occurrence matrix showing the ingredients as subjects and the animals or aspect of animals key elements in patent family claims.

Results

The method outlined before has been applied to analyze the strategy of several competitors in the market of prebiotics and probiotics for the gut health of livestock. In this industry where the market is expanding, the protection of new ingredients or the new combination of ingredients open opportunities to step into said market.

To test the combination of the two techniques, a techmining exercise was developed following the nine steps of the decision phases and the techmining process (Porter and Cunningham 2005).

A search in a patent database with output of data from one member of each patent family selected according to the criteria previously described, brought 1993 patent families, including information about years, inventors, assignees, title, abstract and claims. With the

natural language processing of a techmining tool, the claims were processed and a group of more than 150,000 claims NLP phrases were extracted.

From them through the use of thesaurus grouping, expert help and cluster suite script for selection of terms and removal of void terms, reduced the number of valid terms from which the probiotic and prebiotic terms were grouped and classified.

The authors then analyzed the assignees to select the most dynamic applying for patents in the later years and the key terms in the claims of said patents, in order to understand how the animal medical nutrition industry is focusing its activity. The search in Thomson Innovation brought about 1993 patent families with a time span of year 2000 through 2015, who are indeed dedicated to animal gut health and not mainly to humans. From which, as a way of example, three of the competitors or players selected either by being active in the later years or by being relevant to the experts, as Nestec, the 'Institute de Recherche Agroalimentaire' INRA and DSM, have been analyzed according to the steps described before. The results show that by means of visualizing the trend and intensity of the patent claim terms protected in time and specially any shift in said terms being protected, means a shift in the interest of any player. Further understanding what and how said terms are being used in a faster way, combining techmining and semantic TRIZ, can be very convenient to decision makers.

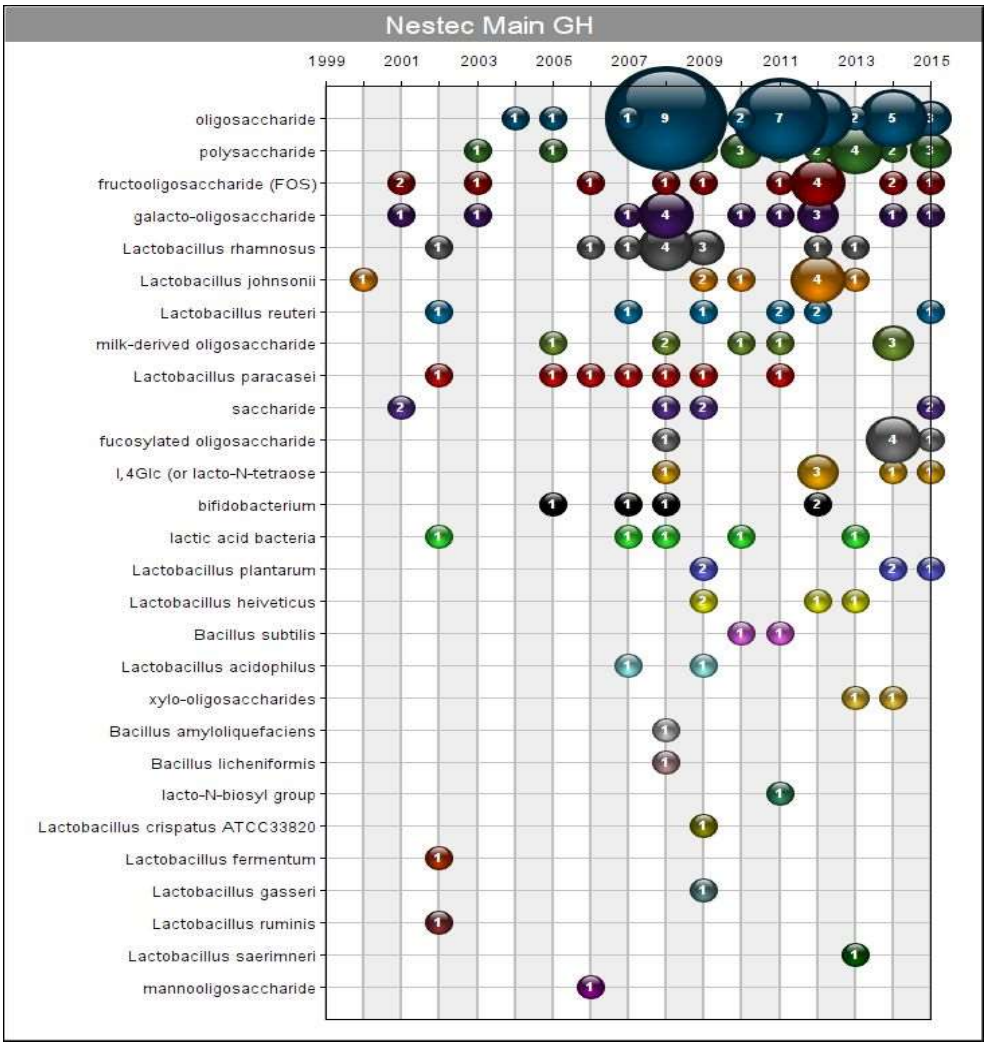


Figure 34. Bubble map with trends about health agent terms in claims of Nestec.

Figure 34 shows a main activity of the company Nestec and its remarkable concentration on the prebiotic components of the family of 'oligosaccharides'. Prebiotics are key since they modulate or change the ratio between 'good' bacteria and microflora and 'bad' bacteria. Prebiotics are mainly used as 'food' for the gut microflora and so its specificity favours some bacteria instead of others. Returning to the figure 34, a decreasing effort

in nonspecific oligosaccharides and a surge of interest in one particular 'fucosylated oligosaccharide' is shown. The authors have seen many of the patents trying to protect the combination of some probiotics with some prebiotics.

'Polysaccharides' and 'lactobacillus johnsonii' seem also to catch some attention. Tables 24 and 25 show some applications of lactobacillus johnsonii and fucosylated oligosaccharide, extracted with a syntactic semantic tool. These applications offer some ideas about how both are being used and therefore offer a guide about their significance. Said applications therefore, offer insights about what could be a possible reason for Nestec to reduce in general oligosaccharide and, to start or to concentrate in fucosylated oligosaccharide. From the use or applications, complemented by expert advice, it seems that this company is positioning in preparing the animal gut. It could point to a strategy which is to focus in the surroundings which may host the probiotics, protected by itself or by other incumbents.

As these terms are extracted from the claims, the presence of such ingredients means the concretion about what the company may be protecting. The next point would be the exact amounts, combinations etc. of ingredients which are beyond the scope of the present paper, but which are also key to the protection of said company.

Table 24. Some key applications of *lactobacillus johnsoni*i as a health agent extracted from the set of patents.

Lactobacillus johnsonii uses or applications	
Inhibition of intestinal invasive pathogen	(5) instances
Inhibition of enterotoxin	(5)

Table 25. Some key applications of *fucosylated oligosaccharid*e as a health agent extracted from the set of patents.

Fucosylated oligosaccharide uses or applications	
As a competitor for pathogens	(2)
Inhibition of stable toxin of Escherichia coli	(2)
As prevention of influenza infection	(1)
For combating multiresistant bacteria	(1)
As health promoter	(1)

The next case is about an Institution present in the market of gut health and more concretely in probiotics and prebiotics for the health of mammals, including humans, as many companies try to reach as broad as possible the potential applications in the medical nutrition industry. This institution was of interest to the experts interested in the present study.

The figure 35 shows some interesting shifts about the claims of the *Institute National de la Rechereche Agroalimentaire*, INRA. In 2003 and 2012-2013 INRA has protected about polysaccharides in the prebiotics. In 2009 and 2010 INRA protected some use about '*lactobacillus sakei'* but in 2014 and 2015 they protect many lactobacillus strains except the lactobacillus sakei. This could mean either they see more interest in other lactobacillus or they have enough protection for lactobacillus sakei. The bubble map does not show clearly any strategy; however, it may call the attention of a subtle change or disruption in a graphical and notorious way. The chart shows only one citation per year due to a comparatively smaller number of patents than the other selected companies. The chart, however, shows a clear shift from protecting the prebiotics 'oligosaccharide' and 'polysaccharides' during the period of 202 to 2014, to a number of different probiotics in 2015 and none prebiotics. By number it may not show a clear trend but in comparing their own portfolio can show a shift in their strategy.

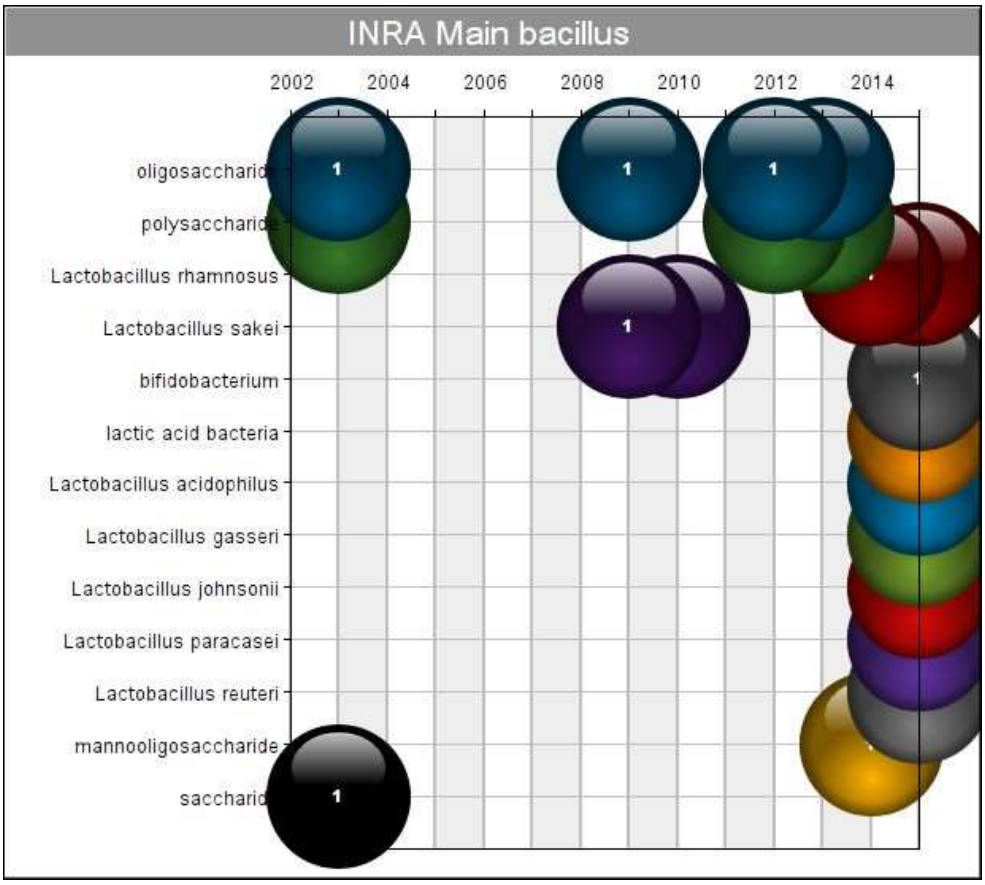


Figure 35. bubble map with trends about health agent terms in claims of INRA.

Table 26 shows some properties about *lactobacillus sakei*. It is worth to mention the high *phytase* activity which is an interesting trend since it may help to reduce the burden of contamination of livestock industry by reducing the amount of phosphorus residues (Kaushik 2015)

Also, to mention in the bubble chart about *lactobacillus rhamnosus*, whose applications are shown in Table 27. To mention the effect against yeast and Escherichia coli, two worrying items for the livestock gut health.

Table 26. Some key applications of lactobacillus sakeii as a health agent extracted from the set of patents.

Lactobacillus Sakei uses or applications	
High phytase activity	(4)
Best antibacterial property	(3)
Improves infection resistance for E. coli	(2)
Produces sakacin A effective against listeria	(2)

Table 27. Some key applications of lactobacillus Rhamnosus as a health agent extracted from the set of patents.

Lactobacillus Rhamnosus uses or applications	
Against Escherichia coli	(5)
Against streptococcus mutant	(5)
Against streptococcus sobrinus	(5)
Inhibition of pro-inflammatory cytokines	(5)
Cure of yeast infection	(4)

Figure 36 shows the bubble chart of DSM IP and its activity in protecting probiotics and prebiotics, mainly in the latter. To mention a great surge in 2012 and 2013 in the prebiotic polysaccharide and a stop in 2010 about oligosaccharides and galacto-oligosaccharides. The applications of the polysaccharide are shown in table 28. Dietary fibre is among the expected uses of any fibre, however the antiviral and antitumor may be less common properties. As in the case of Nestec, this group of big players in the animal health industry seem to concentrate in the surroundings, in this case, the preparation of the animal gut lining, maybe to be able to protect later possible probiotics in the future.

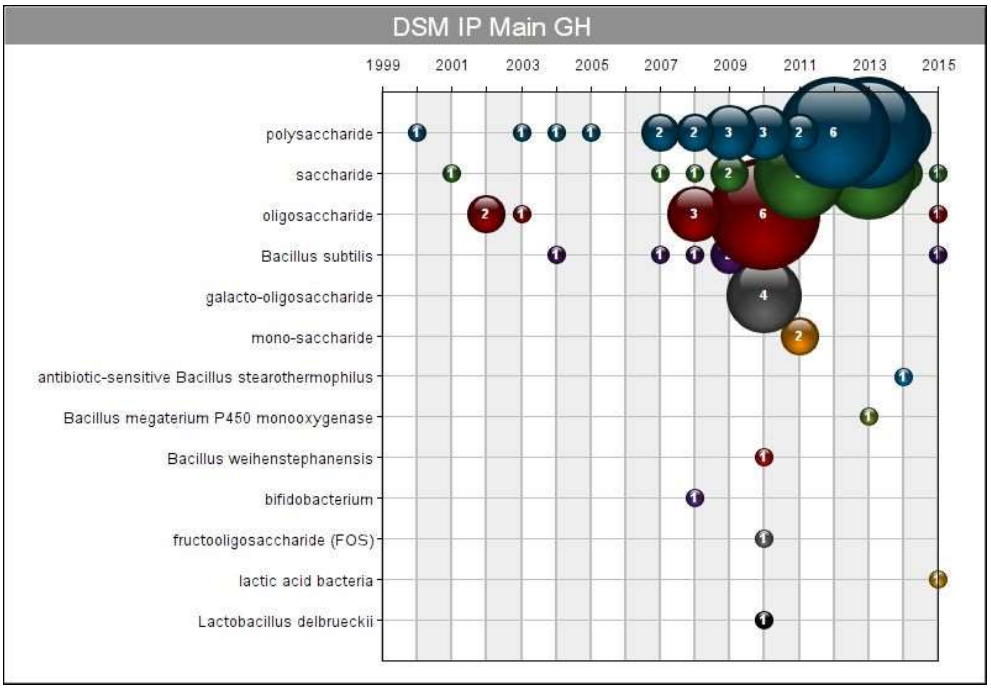


Figure 36. bubble map with trends about health agent terms in claims of DSM IP.

Table 28. Some key applications of the prebiotic family of polysaccharides as health agent extracted from the set of patents.

Polysaccharide applications in animal gut health	
For antibody generation	(20)
As antitumor agent	(12)
As antiviral agent	(11)
As pneumococcal vaccine	(11)
As dietary fiber	(10)

Discussion and Conclusions

The framework outlined here brought in a visual form and using standard procedures, a method to quickly detect changes or small disruptions in the protection strategy of competitor firms. The combination of a techmining approach, complemented further with that of semantic TRIZ, can propose a simple, yet direct, method to detect changes in the strategic intent of different companies, reflected in shifts or continued effort through the terms extracted from their claims in their patent portfolio and quickly seeing the purpose of such terms through their uses or applications extracted from the claims and complemented with those of the descriptions.

Having analyzed the claims of the patents in the nutraceutical brings advantages in front of traditional title/abstract approaches. Finding the key terms in the claims and their pattern against time, is a direct indicator of what companies are trying to protect and therefore central to the strategy of said company. Furthermore, as we have outlined that claims are richer in the key terms and very precise in citing such key terms with respect to titles and abstracts, the proposed method brings closer to detect any new ingredient or coadjuvant a company tries to protect. In conclusion, we may say that by mining claims we analyzed more and more relevant terms related to the strategy of a company.

The help of the semantic analysis quickly helps to understand the context and the purpose of the new terms signaling the direction of the patent strategy of a company, with less expert involvement. The different number of citations in the uses or applications is due to the number of patents analyzed for each company and to the extent of prebiotics as polysaccharides which are combined with the claim of new probiotics.

In the present study, each company had their own participation in the nutraceutical industry and so the number of patents each company has filed. The scope has been to analyze each company isolated to detect changes in its patenting behavior. An interesting and complementing approach could be to compare dynamically the strategy of all participants in the industry to detect which is expanding into the white space of others or vice versa.

The present framework needs further investigation. For instance, it is worth to check the application of the present method to different technologies of other industries different than in the medical nutrition industry where expanding the protection of substances as an alternative to antibiotics is the main strategy. In this industry, the market is expanding, therefore the protection of new ingredients or the new combination of ingredients, open opportunities to step into said market.

For instance, in the hardware industry, it is necessary to check if the shift of claim terms in time, corresponds to relevant positions or a change in the strategies of involve companies. Maybe in mechanical or electronic domains where new components may have more or less impact in the opportunities of the company, further dimensions should be considered. Another element to further explore, is the use of other visualization tools

using also information about the market to better understand the possible movements in the protection through patents.

A more comprehensive study could be performed comparing the extraction of terms from claims compared to other parts of the same patent portfolios of the selected companies. One limitation of the present study is the lack of a longer period of time or to be able to explore if the current changes in strategy are steady in the future. Another limitation is the scarce involvement in patenting of some companies in the analyzed domain. Companies are trying to bet their presence in the market space, by protecting now what is thought to be of real value in the near future.

The present study helps to detect changes in the strategy, further analysis should be carried to fully understand the impact of any change in the strategy of the involved companies. The study about priorities and countries covered should also be added for analyzing and understanding any change in the technology strategy.

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Chapter 10
Discussion and Conclusions

The present thesis intends to present the advantages of combining both methods with a point of view of the systemic approach of the technologies being analyzed.

The systemic point of view can help to measure structural relationships among components of a technology. It can also help to understand the links between research areas, related by the technologies to which they pertain. The systemic approach offers a view of the relative relevance of each component in terms of adding value to a given technology. This latter may help to measure the relative relevance of trends, with the help of techmining, in research works about monitoring the progress of a given technology.

Semantic analysis, jointly with the systemic view may complement scientometrics techniques such as IPC analysis, co-word analysis, co-citation analysis or coupling analysis, morphology analysis, etc. in the task of assessing technology evolution. Especially in open innovation, companies require more information about key technologies outside their own, their usage in different industries and the actors behind them.

The semantic and syntactic structure of the key technologies, with problems, functions and components, in a technology field, can offer a functional-value map which may help to identify the limiting/enabling technologies, key bottlenecks of a technology field and help to identify the key partners behind such key bottlenecks, gaining advantages in technology partner selection.

The combination of techmining and semantic TRIZ add some other dimension to the analysis of technology evolution through the analysis of scientific and technical literature.

The combination of techmining and semantic TRIZ allows to analyze the parallel trend of some components in a system and in other technologies: This parallel trend can pose questions such as who is 'driving' whom, *the hen or the egg*, and therefore may determine the outcome.

The functional linkage of components in a system and environment, driven by the internal parameters in relation, helps to see a more complete, yet logic view of the system and ecosystem. The vision of the ecosystem may help to better predict the outcome of an emerging technology supported by techmining and semantic TRIZ.

Different applications have been explored in the present compendium and increasingly, more research is being published either using some elements of the semantic analysis and even distinguishing partitive elements from attributes and its role in technology evolution assessment. The present combination seems to be of increasing interest.

The different applications of the combined approach explored through the publication of the different papers show a limitation based on, or depending on, the capacity of understanding the essence of the technologies and its functional deployment. Therefore, it can be less easy or less repeatable to use than quantitative methods more statistically accurate, as some of the works cited in the introduction or in the proposed methodology (e.g. Guo et al. 2016; Wang et al. 2017). The analysis of the system requires a deep comprehension and a state of the art revision for determining components, their functions or role and the bottlenecks in the system. The participation of some specialists for validation is needed, making difficult to be repeated in a more systematic approach. The advancement of the semantic tools is allowing to automatically find functions relating components, however, it is still today a singular approach not yet generalized. Some authors (e.g. Yang et al. 2016) have criticized the inaccuracy of the semantic analysis to extract all the possible existing relationships and therefore questioning the validity of the analysis done with such methods. The author recognize such limitations, however using the system and further being supported by a full Techmining approach can improve the usage of the semantic analysis and to bring the benefit of both worlds.

In the LBD process, the combined method of applying a semantic and syntactic approach, added a small step that is only the beginning of the use of semantics to link unconnected concepts. Again, it can be less quantitative or exhaustive since the tools understanding the logical links, are not exhaustive as it is mentioned in the second paper. However, with the improvement of artificial intelligence, the semantic tools combined with the also improved tools in techmining can further improve and so may close the gap with quantitative methods (e.g. Swanson 2008; Kostoff 2008). There are two main approaches in LBD one closed and one open. By using the semantic approach, the natural way of exploring the discovery of new connections is in an open mode. In a closed mode,

perhaps the established method of applying techmining to extract all terms and afterwards make the connections may be better than the semantic approach.

The paper here presented was a simple proof of concept. It is possible to perform a closed LBD approach besides the open approach tested. Further research and a broader scope of the documentation to be analyzed should be done. Either by including a larger and more extensive initial search or by performing more directions and with deeper cause-effect links. The author hopes that in the next future can find collaboration and time to undertake a more ambitious test of the method.

The proposition of applying techmining to the patent claims has been limited to a specific field where companies need to cite the key ingredients in the claim to benefit from protection. A possible limitation for this approach could be in technologies where the functions are more relevant than the components, and therefore the extraction of terms could not be so successful. Therefore, it is worth to check the application of the present method to different technologies of other industries different than in the medical nutrition industry where expanding the protection of substances as an alternative to antibiotics is the main strategy. Another possible scenario which needs further exploration is in sectors where the citation of components could have more or less impact in the strategy of the company. This would add a second variable not yet explored in the fourth article. The visualization method proposed is accessory, but in order to be complemented with market information to better understand the shifts in strategy of the companies.

A more comprehensive study could be performed comparing the extraction of terms from claims with respect to other parts of the same patent portfolios of the selected companies.

Another limitation in the exploration done is the lack of a longer time period exploration. Specially in exploring the effects of the shifts in strategy and their impact in adjacent technologies. Also in understanding the different changes in time of a company. Finally, the study about priorities and countries covered should also be added this research for analyzing and better understanding any change in the technology strategy.

Chapter 11
Future research

The present compendium is just a group of applications of the combination of techmining and semantic TRIZ. Many possibilities offer this combination and the author is undertaking new applications for the analysis of different technologies in next research to be published. Complementary, the mounting research using subject-action-object will also reinforce the combination here presented. The author is eager to explore the combination of both techniques for further assessment of technologies and science advancement, as well as monitoring and foreseeing the advancements in assessing the evolution of a technology.

The application of the combination to the root-cause analysis approach could set a new way of research, linking logic concepts and tree branches about any subject. Instead of reviewing different lines and having to link the time and reading of many papers, a root-cause logic linking the causes of a subject e.g. a disease, can establish lines of research which can be assessed with the help of techmining. The author presented a contribution in this sense at the Congress of ATISR in Korea although yet to be developed and presented as a paper.

The construction of systems and functionally linked components of their ecosystem in a broader sense, may be assessed with techmining to evaluate the evolution and to test the phrase of Adner and Kapoor 2016, '*a technology is as good as its ecosystem'*. This is a line of research that the author will try to undertake.

The validity of the systemic approach should be measured in the analysis of a past period to check if the systemic approach really helped to predict what finally occurred. Another test to be further researched is to compare the systemic approach with that of the morphologic approach undertook by the Beijing Institute of Technology, for the better understanding of the evolution of a technology.

Finally, the limitations listed so far provide different tasks of research, to expand and further prove that the combination can bring advantages in technology analysis.

Chapter 12
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