Combining patent forward citation and TRIZ analysis in a simple method for the identification of major innovations from a specific technology field.

MARQUES, Christiane de Fátima Silva[1,2]; FONSECA, Marcus Vinícius de Araújo[3]
Email: marques.christiane@gmail.com[1]; vfonseca@labrinto.coppe.ufrj.br[3]
[1] Federal University of Rio de Janeiro; [2] Oswaldo Cruz Foundation - Rio de Janeiro, Brazil

Abstract

The present study combines patent forward citation count and TRIZ analysis in a method for the identification of the major impact inventions on the modern biotechnology, a highly dynamic, knowledge-based area, on which patents are considered a crucial instrument for intellectual property protection. The combination of patent forward citation and inventive level analyses was applied on the 0.3% most cited patents related to biotechnology applied to the human health, focusing the in vitro diagnostic reagents niche. Documents were retrieved from an online database, and analysed by the perspective of TRIZ inventive principles, engineering parameters and inventive levels. All significant inventions on the modern biotechnology area could be identified in the selected resulting group, confirming that the proposed method was able to identify the best, valuable and innovative patents in a specific R&D area. The resulting robust patent list can provide core information on major trends, players, expiration dates and free operation niches, for example, without an overwhelming amount of documents and the need of expensive or user-unfriendly software or packages. It can also be elected as a starting list for further patentometric initiatives. The proposed methodology can be used as basic framework to perform modest, yet pertinent studies on specific technical fields or technologies. The combination of these patent analysis information as a tool for innovation management can be also be adapted to other several knowledge areas, and help academic, corporate and government foresight and forecasting studies, for example, by increasing the innovation impact of worldwide research and development initiatives, and ultimately, industry performance.

Keywords

TRIZ; patent analysis; tech mining; forward citation; biotechnology; innovation.

Introduction

Some authors consider patents as ambiguous entities, due to the flaws on the methods by which they are written, classified and cited [1-3]. Other limitations from the patent system are also frequently considered, such as the industrial secret protection, the 18-month confidentiality period, the specificities of distinct countries versus the general rules, and singularities of some technological sectors regarding patent strategies [4,5].

Despite the permanent and intense discussion on the value of patents as innovation and scientific progress indicators, the fact that such documents join precious and high quality information that can be used on technology management is out of question [3, 6, 7]. Besides that, patent statistics are readily available, objective, quantifiable, and informative. The number of patents by year, organization or nation, can easily be known and help decision-makers regarding technology waves and ways [8].

Patent documents concentrate more than 2/3 of all technology information (WIPO, 2015). Besides that, the advantages of using the patent system on technology monitoring and assessment rely on the worldwide and technology field coverage, universality of document format, continuous growth, and the potential of reducing 30% of research and development (R&D) costs by excluding duplicate efforts [4]

The previous argument is, of course, strongly supported by the biopharmaceutical industry, but it does not mean it is not valid. The patent system has made it possible for those companies to overcome the risky, extensive, laborious and expensive process of developing new drugs to save or maintain lives all over the world [9].

Patents did encourage basic research and technological development of patent-protected technologies by using the 'research exemption' [9], for example, to test for molecules or pathways that can be applied into conditions or diseases that are distinct from the ones that have been claimed in a specific patent document.

Patent analysis can be used as a tool for advising R&D projects, by monitoring specific technologies, identifying technical alternatives and expertise sources, accessing IP value and the efficiency of R&D processes in a firm [8]. It can also be fully implemented on foresight studies, as an instrument for understanding the technological position in the competitive landscape, for market analysis related to the strategic planning. Finally, it may also help understanding the interdependence relationships between technologies and their

consequences to the organization, industry or country, as well as for assessing the impact of innovation policies [9,10].

Patent citation analysis has been one of the most common tools to measure the influence of patents on subsequent technological developments [11-13]. Forward citation count has been highly correlated to technical importance, as well as positively linked to social returns to innovation, affecting economic-based indicators [8].

However, adopting citation count alone is not the best way to analyse and value patents, for many reasons. Examples include incomplete or invalid citation lists [2], auto citations, non-linear association with patent value [13] and the time needed for a patent to be recognized and cited by newer patent documents, which favours older patents in general [1].

Nevertheless, groups [2, 14] and have confirmed forward citations as a primary factor in patent ranking, even more significant than age (range of years from priority), claim count, family size and international fillings. They have found that sold and representative patents had exponentially more forward citations than the broad set of issued patents from 2005 to 2014, as well as slightly reduced set of litigated patents in several fields.

Developed by Genrich Altshuller on the 1940's [15], the Theory of Inventive Problem Solving (TRIZ) is one of the most commonly used heuristic method for new product ideation, based on the rules and patterns that are present on the creative process [16].

By analysing patent documents from several distinct areas, Altshuller have proved that a small number of basic, universal possibilities for solving problems can be widely applied to distinct fields. As a conclusion, the author states that most inventive problems can be eliminated by using previously described experiments and solutions, provided that they are presented explicitly as principles and standards [16].

TRIZ was further developed to be a systematic method for problem solving and organizational learning [17], as it became a form of appropriation of technology-related knowledge, reflecting the accumulated knowledge in a given area, based on the original information of patent documents. Consequently, TRIZ elements can enrich technology foresight and forecasting activities, lead research towards satisfactory solutions to technical bottlenecks, as well as identify trends and technological opportunities as a background scenario for new inventions [16, 18].

The successful application of TRIZ can be exemplified by citing big companies, such as Boeing (BA), Hewlett Packard (HPQ), IBM (IBM), Motorola (MOT), Xerox (XRX), and the most famous or well-documented case, Samsung (SSNLF) [19]. Moreover, several authors have demonstrated distinct ways of performing TRIZ analysis and have contributed with creative applications and computer-aided tools [20-22].

Altshuller and his colleagues identified five levels of inventiveness based on problem difficulty, dissimilarity between a previous prototypes and the new solution, and the knowledge that was required from the inventor's field (or from a distinct field) that was needed to come to the new solution [15]. Patents representing artless adjustments to an earlier design were assigned to Level 1, inventions expressing significant changes to the original system were considered intermediate, and patents presenting a new science or original technology were classified into Level 5, the most innovative [17].

Specifically, on the biotechnology area, the protection of the intellectual property is such a fundamental feature that the Diamond versus Chakrabarty's trial in 1980 was the pulse trigger for the whole industry. On that occasion, the US court ruled in favour of granting a patent for a genetically modified bacterium, legitimating the appropriateness of inventions in this area, starting a new era of private progressive investment, and rapidly expanding patenting of new products and biotechnological processes [7, 23, 24]. Following that, human recombinant insulin, released in 1982 by Genentech-Eli Lilly's consortium), can be pointed out as the first biotechnology-based therapy approved by the FDA [24].

Considering that only 0.3% of patent documents mention real outstanding innovations, according to TRIZ premises [15], and that forward citations are predictors of patent value, we have formulated and tested the hypothesis that the combination of these two aspects could indicate the best, valuable and innovative patents in a specific R&D area.

In order to test the hypothesis, we have chosen the highly dynamic, technology density, knowledge-based area of biotechnology applied to the human health, focusing the *in vitro* diagnostic reagents niche. The combination of patent forward citation and inventive level analyses was applied as a basic method for theory development.

Biotechnology is characterized as a productive chain with high added value. Thus, the final product markets of this production chain will always be present when we focus on commercial interests related to the corresponding patents. The study proposed here is a

way of evaluating the synergy of actions and activities directly related to the competitiveness of companies operating in the area of biotechnology.

Material and Methods

As a strategy for challenging our hypothesis, we have submitted the query combining the International Patent Codes (IPC) C12N and G01N-033 to the online Derwent Innovations Index® (Thomson Reuters) patent database. The first IPC code is related to mutation or genetic engineering and the use of micro-organisms, and the second states for methods of measuring, testing, investigating or analysing materials. Resulting documents were representative from the biotechnology field, human health subfield, emphasizing on the reagents for *in vitro* and *in vivo* diagnostic.

Search was limited to the 35-year period encompassing modern biotechnology inventions (1980 to 2015). Documents were retrieved, and sorted by the number of forward citations. The 0.3% most cited patents were selected and analyzed, according to the TRIZ premises and elements, by means of individual record reading, especially of the fields 'Title', 'Abstract', 'Use', and 'Advantage'. Claims were also reviewed, since they define the essential novel and detailed features of the innovation, as well as the legal aspects they cover [8, 10]. Should inconsistencies or doubts prevail, the full background and summary of the invention were read for clarification.

We have adopted, with minor adaptations, the standard form of experimental patent study and the basic flowchart of patent investigation that were brought to light as a registry for patent findings, in terms of traditional TRIZ [17]. In addition, authors developed a basic scheme for studying each single patent, considering the five inventive levels, 40 Inventive Principles and 39 engineering parameters initially formulated by Genrich Altshuller and generalized by TRIZ specialists from the Virtual TRIZ College [15, 16]. Excel®, Vantage Point®, Gephi® and Wordle (www.wordle.net) were used for data analysis and visualization.

Results and Discussion

In the biotechnology area, one of the most innovation-intense industries, patents are taken seriously as an effective mean for protecting intellectual property, and they play a

critical, strategic role on the companies' performance [8]. Despite of what happens on other technological fields, keeping an industrial secret or making a preventive publishing are not common practices in this area, and biotechnology patents attracts attention as indicators of R&D outcomes.

The present work has focused on the IVD reagents as a model for testing the hypothesis of combining TRIZ and forward citation count resulting on a novel and successful patent analysis method. Therefore, it was concentrated on patents with IPC codes related to products, devices and processes with diagnostic purposes or intended applications, originated on biotechnology methods [27].

We have retrieved 57,799 from the 28,476,755 documents available at Derwent Innovations Index® at the time of the data collection by using the combined, truncated IPC terms C12N* AND G01N-033*, and the timespan of 1980 to 2015 in the basic search tool.

One must bear in mind that not all inventions become a product, and when they do, it takes some time. As suggested by some authors [8, 29] a high degree of innovation may slow down the diffusion of the patented invention. The choice of using such a wide timeframe for the search query is in accordance with this argumentation. However, at the same time, we are aware of the limitations coming from such recently granted patents (<15 years) that were retrieved.

The application of the subject area filter (Biotechnology and Applied Microbiology) available at the data source platform has excluded less than 4% of documents (54,827 from 57,010 original patents). None of them was among the most cited ones. We believe that this exclusion has positively refined our analysis, since the profiles of both groups remained very similar, regarding major players and subject areas other than biotechnology.

Documents were subsequently sorted by the number of times they were cited, and the 0,3% (N= 167) most cited patents were selected and listed separately. At that point, documents were downloaded, registered, and analyzed.

Patents were classified into IPC classes from the modern biotechnology area, reflecting products and processes related to the recombinant DNA-technology. This catalogue encompasses compounds and preparation of compounds with nucleic acids or nucleotides, and measuring or testing materials such as peptides and immunoglobulins, microorganisms, medicinal preparations containing antigens or antibodies, chemical,

physical, or physic-chemical processes in general, as well as apparatus for enzymology or microbiology, confirming that the strategy fit to the focusing on the diagnostic market.

The first part of the analysis has revealed the basic profile of the documents. Table 1 shows top 10 IPC codes mentioned on the 167 (0.3% most cited) patents. Several distinct codes were identified (N=1038; Mean=6/patent; approximately 30/year), indicating a high potential of these inventions regarding their wide application, use expansion, and association with different technologies and fields. This is reinforced by the high number of IPC classes (4-digit IPC codes) that were observed (N=102) in this group of patents.

TABLE 1 – Top 10 IPC codes used on the classification of 167 (0.3% most cited) patents.

IPC CODE	N	%
C12N-015-09	116	69.5
C12Q-001/68	114	68.3
G01N-033/53	87	52.1
C07H-021/04	86	51.5
C12N-015/00	72	43.1
G01N-033/50	63	37.7
G01N-033/566	61	36.5
C12P-019/34	55	32.9
C07H-021/00	48	28.7
C07H-021/02	48	28.7

Table 2 shows the top 20 assignees in the 167 selected documents, which have contributed to 3 or more patents (N=94; 56.3%), disregarding co-ownerships. Some of these major players concentrate their contribution in short periods, such as Cambridge Antibody Technology, Medical Research Council and Medimmune LTDA (patents dating from 1992-1993). In contrast, others (Genentech Corp, Chiron Corp and Affymax) have patents granted over several years, showing a greater consistency in innovation performance and IP strategy.

Regarding the main players on the modern biotechnology context, our data corroborate previous findings [8], outlining Affymax/Affymetrix, Genentech and Chiron as important firms. Documents from other pioneers (Eli Lilly, Bayer, Biogen and RhonePouenc) were also retrieved by the search query. They were also leading enterprises of first identifiable biotechnology patents [5].

TABLE 2 - Top 20 patent assignee(s) from 167 documents.

ASSIGNEE CONVENTIONAL NAME	N (each)	% (each)
Genentech Inc	9	5.4
Affymax Technologies	8	4.8
Cambridge Antibody Technology Chiron Corp Medical Res Council	6	3.6
Cetus Oncology Corp Univ California	5	3.0
Affymetrix Inc Applera Corp Hoffmann La Roche and CO Perkin Elmer Corp	4	2.4
Abbot Biotechnology LTD Bayer Corp Celltech R&D LTD Ciba Corning Diagnostics Corp Isis Pharm Inc Koster H Massachusetts Inst Technology Medimune LTD Nanogen Inc Northrup M A Sequenom Inc	3	1.8

Three from top 10 major players (Genentech, Hoffman La Roche, and University of California) are the same on the 57,799 original documents and on the 167 most cited patents. These institutions have a brilliant history on the biotechnology area, reflected on the value of their patents, considering the great number of times they are cited and the best-selling biotechnology products they have made available to the market, as either standalone companies, as well as part of successful collaboration consortiums [5,26].

Merges and acquisitions between biotech-biotech and pharma-biotech are common and may alter this landscape, depending on the adopted strategies for portfolio management. For example, if Affymerix and Affymax shall be joined as one (considering that the first is a spin-off of the later), they would own 12 patents in the 167+ group, outnumbering Genentech. Furthermore, the distinction between pharmaceutical and biotechnology companies is becoming distorted, and “biopharmaceuticals” has been used as a more accurate descriptor [5].

The number of claims in the documents ranged from five to 329, with a mean of 44 distinct applications protected in each patent.

The majority of patents have the United States as the priority country (130/164, 79.3%), followed by Great Britain (17/164, 10.4%), Japan (5/164, 3%), Denmark and France (3/164, 1.8% each), and Switzerland (2/164, 1.2%). Finland, Germany, Netherlands and Sweden were priority countries of one patent each.

Our data corroborate findings from a previous and wide analysis on the territory concentration of priority patent deposits and awards [5]. We have also observed that the majority of selected patents were from organizations based on the United States, followed by Europe and Asia.

Following this pattern, as well as the need of sending specimens to the international repository, WIPO has granted 67% (112/167) of these patents, followed by EPO (45/167, 27%).

Regarding patent age, the major part of the documents from our refined cohort (N= 93, 55.7%) had 20-29 years from application date (Table 3). Patents as old as 34 and as young as 9 years-old have been included, and the average age was 22 years.

Average number of forward citations from a single document was 379, and ranged from 179 to 4288. Counts lower than 500 were observed in a pronounced number of patents (N= 143, 85.6%), as also shown in Table 3. Number of citations per year was then calculated. It ranged from six to 194, with an average of 17. The majority of the patents had up to 24 citations per year (N= 148, 88.6%).

Our data corroborate previous findings [1, 12] regarding a great number of patents that are never cited: 40% of the documents from our initial cohort (N=22,028/55,609). A potential extension for the present work would be the analysis of these documents, in order to understand if they use low inventive level solutions, and if there are additional explanations for their lack of value as reference for further inventions, such as being very recently published and/or coming from small, inexpressive patent families.

Even the less cited patents from this group had an index that can be considered truly high, since they outnumber the average absolute number of six citations in 10 years [12]. According to some authors, 75% of patents are cited in a maximum of 5 times and only 1% of them gets a high citation count of 24 or more times, in general. These findings indicate

that this group is indeed composed by high value patents that concentrates critical biotechnology knowledge.

Table 3
Age and citation information from 167 patent documents.

Patent Age	N	%	Times Cited	N	%	Citations/year	N	%
> 30 years	16	9.6	4288 - 2000	2	1.2	> 100	2	1.2
29-20 years	93	55.7	1999 - 1000	4	2.4	99 - 50	4	2.4
19-10 years	57	34.1	999 - 500	18	10.8	49 - 10	121	72.5
< 10 years	1	0.6	499 - 179	143	85.6	< 10	40	23.9

An expected limitation of our work would be related to the fact that recently granted patents would have less citations [1, 28], yet they could contain significant innovative elements.

However, the analysis of the documents cited less than 10 times per year have revealed both as recent as 2014-2015, and as ancient as 1985-1986 patents (primary access number designated by the base), indicating that they have not been cited because they were not recognized as technically or historically relevant, not exclusively because they are new [30].

The first part of TRIZ analysis was based on the classification of the inventions described in the documents according to the 40 inventive principles and 39 engineering parameters.

Top five inventive principles were local quality, segmentation (or fragmentation), copying, merging and intermediary. Top five engineering parameters were amount of substance, complexity, accuracy of measuring, productivity, area.

Biotechnology could contribute to the list of 40 inventive principles by adding ‘complementarity’ as second item for the principle 33 (homogeneity). In a simplistic description, homogeneity-based solutions relate to making objects interact with a given object of the same material, or material with identical properties [17].

In order to incorporate the crucial feature of DNA, RNA and protein sequences reflecting the basic composition of the target molecules used in most biotechnology techniques, ‘complementarity’ should be considered as a group of solutions that allows molecules interact one to each other by taking advantage of the nucleotide sequence

complementarity. From another perspective, it could be represented in the list of engineering parameters, by adding the term ‘nucleotide sequence’ on the first cluster, related to common physical and geometric characteristics.

In the suggested scenario, ‘complementarity’ and ‘nucleotide sequence’ would certainly appear in the top five classification for principles and parameters, since they are very useful features and basics on biotechnology methods for amplifying, sequencing, detecting and producing new or target molecules.

The principles and parameters reflect the evolutionary trends and ideality concepts on biotechnology systems: automation, compartmentalization, signal or substance amplification, parallelism, functional evolution and miniaturization.

The second part of TRIZ analysis was based on the inventive level classification of the 167 documents. It has resulted on the identification of patents describing inventions from levels 2-4 (Table 4). Intermediary inventive level solutions were present in 43.7% (N= 73) of the documents. Inventions were mostly concentrated on the higher inventive levels (3 and 4), as confirmed by the comparison of observed and expected percentages according to TRIZ.

Table 4
Inventive levels from top 167 most cited biotechnology patents and their observed (obs) and expected (exp) percentiles.

Inventive Level	N	% (obs)	% (exp)
1 – Regular, rationalization	0	0.00	32
2 – Improvement, modernization	57	34.1	45
3 – Invention inside paradigm, innovation	73	43.7	18
4 – Breakthrough outside paradigm, synthesis	37	22.2	4
5 – Discovery, new effects and phenomena	0	0	<1

On the present work, 37 patents (22.2%) represented high inventive level documents. Some of them were hard to categorize, since they related to DNA amplification, production of recombinant antibodies, immunotherapy, in vitro cell and tissue culture, transgenic animals, polymorphisms as biomarkers, viral and bacterial genomes in detail. These patents disclose major biotechnology achievements, and could be dually or subjectively classified on the border of levels 4 to 5.

As TRIZ concepts are centred on the selection and study of high-level patents, we have hypothesized that the most relevant patents in a specific area would be in the intersection of greater inventiveness level and outnumbered patent forward citation count.

By analysing the forward citation counts and TRIZ inventive levels, it was observed that 15 patents (35.7%) with citations above the group average (> 379) were classified as belonging to level 4, in a greater proportion than those with lower citation counts (22/125, 17.6%) (Table 5).

Table 5
Combined analysis of forward citation count and TRIZ inventive levels on the 167 most cited biotechnology patents.

Forward Ciation Count	**> 379**		**< 379**	
Inventive Level	**N**	**%**	**N**	**%**
2	8	19	49	39.2
3	19	45.2	54	43.2
4	15	35.7	22	17.6

In accordance to our initial hypothesis, main solutions to inventive biotechnology problems were observed on the group of documents with the highest number of forward citations. However, despite of what was expected, level 2-3 solutions were represented on the top 167 most cited patent documents from our cohort. In spite of that, the resulting group of patents exemplified state of the art technologies and trends, representing a faithful summary of the past 35 years' major achievements in this technologic field.

The quality aggregation of products and processes associated with incremental innovations are certainly the initial steps to add competitiveness to the organizational portfolio. However, the permanent search for a paradigm break in sectors whose dominant technologies life cycle is coming to an end is also a strong inducer of radical innovation.

The advance towards breakthrough technologies and radical innovations is normally associated to the first stage of the technology life cycle, which means market uncertainty and high-risk R&D efforts. On the other hand, it also means a greater opportunity to break down paradigms, trace new technology waves and routes, and give birth to new industries, market approaches and bonus innovations [8].

Conclusions and Perspectives

The present work has embraced TRIZ as a starting point and coordinating concept for testing a new theory of technical systems and technological inventive and innovative processes.

TRIZ analysis have resulted in distinct, creative applications and computer-aided tools [20-22, 25]. However, it is not of our knowledge any study combining TRIZ tools with patent citation analysis in order to provide a simplistic, yet enlightening way of recovering key technology information. Present work could overcome common difficulties from TRIZ analysis, such as long lists and noisy results [21].

One of the recommendations for TRIZ analysis is not to restrict search method by using standard keyword-based or classifications such as IPC to avoid ignoring relevant and enlightening solutions from other fields [21]. We have accepted this constraint, bearing in mind that the focus of the analysis was to retrieve documents related to biotechnology solutions for human health. Even then, we have observed the influence of related out-boundary technology fields, such as polymer science and energy and fuels.

By overcoming the problem of the huge amount of documents where information shall be accurately and quickly extracted from, the method for obtaining a general overview of technology niches based on a pool of valuable patent documents [7] can be used as a state of the art for product development reference and identification of technological opportunities.

With such a reduced number of documents to be analyzed, studies can be easily and quickly accomplished, providing relevant, qualified technologic information for researches as well as for technology managers and investors.

Resulting robust patent list can provide core information on major trends, players, expiration dates and free operation niches, for example, without an overwhelming amount of documents and the need of expensive or user-unfriendly software or packages. It can also be elected as a starting list for further patentometric initiatives.

Part of the present work was limited by the option of not using a patent/text mining software, so that it could be performed by anyone without the need of investing on the acquisition of licenses or hiring online platforms. Another possible approach would be to

adopt and compare distinct software suites as tools for the proposed TRIZ and forward citation combined patent analysis.

Although the basic assumption of a direct correlation between forward citation count and TRIZ inventive level classification could not be sustained, the initial hypothesis of a positive result from the combination of these filters in a patent analysis study was demonstrated.

The proposed methodology can be used as basic framework, allowing students and other investigators to perform modest, yet pertinent studies on specific technical fields or technologies.

The combination of these patent analysis information as a tool for innovation management can be also be adapted to other several knowledge areas, and help academic, corporate and government foresight and forecasting studies, for example, by increasing the innovation impact of worldwide research and development initiatives, and ultimately, industry performance.

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