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Patent Data Driven Innovation Logic: Textual pattern exploration to identify innovation logic data

Simon Dewulf

AULIVE Pty Ltd, Glen Elgin, NSW 2370, AU
s@aulive.com

Abstract. Abstract

This paper introduces, examines and confirms that text patterns that identify properties, functions, values, solutions in patent literature. Text patterns can augment the full innovation logic process. The research proposed the use of adjectives for property identification and verbs for functions. It is furthermore shown that there is a context independent relations between properties and functions, or adjectives and verbs. Specific patterns will be proposed for each step in the innovation logic process. The proposed Innovation Logic process contains three distinct steps; wish, shop and create. Artificial innovation methods can be fueled by using these text patterns in patent data. Patent Data Driven Innovation Logic demonstrates a systematic innovation approach that combines the force of contemporary data mining methods on patent literature, with a structured innovation research methodology. A toothbrush is used as a case study. This paper contains excerpts of the PhD 'Patent Data Driven Innovation Logic' [1].

Keywords: Patent Analysis, AI, property-function, Innovation Logic.

1 Introduction

Patents contain a large corpus of technical data that is not available elsewhere. They are therefore very interesting for both academia and industry [2]. The patent database is a large source of free technical knowledge that describes, explains and reveals current technologies used, and provides solutions to problems [3]. Patents are an increasingly important source of technological intelligence that companies can use to gain strategic advantage. They can be used as a stimulus for R&D in searching for whether someone, somewhere has already solved the problem, or an analogous one.

Text Mining and Knowledge Management technologies are assuming a key role for many organisations, in order to propose competitive products or services it is necessary to minimise the resources dedicated to the accomplishment of repetitive tasks and to focus on 'creative' activities [4].

The rapid increase in worldwide patent data requires algorithms or ways to structure the data to retrieve the information required, with a minimum time or effort. Text mining of patents is the data science of analysing a large amount of intellectual property information, to discover relationships, trends, and patterns in the data for decision mak-

ing. It is a multidisciplinary approach that makes use of mathematics, statistics, computer programming, and operations research to gain valuable knowledge from data, to support decision making rooted in the business context [5, 6, 7] and within innovation methodologies.

In the paper we will explore how text patterns can identify innovation logic data. Innovation Logic is a 3 step process for idea generation. Firstly, Wish, is a step to identify the value factors in a product or process. Secondly, Shop, is to identify where to look outside one's domain to find new inspiration, technologies, solutions. Third and lastly, Create, is a process of varying properties to create new or improved functions. The aim of this paper is to demonstrate text patterns that will automatically distil the relevant information out of patent data. Below is a summary of patent text mining for systematic innovation methods [1].

1.1 Patent and Database Structure text mining

- Patent Document Format [4, 8, 9, 10]
- Citations [4, 6, 7, 11, 12, 13]
- Patent Classification [7, 8, 14, 15, 16, 17]

1.2 Patent Text mining approaches

- Keywords [9, 11, 17, 18, 19, 20]
- Verb-Object [3, 4, 16, 21, 22, 23, 24]
- Subject-Action-Object (SAO) [4, 7, 25, 26, 27, 28, 29, 30]
- Adjective – Verb [17, 31, 32, 33, 34]

1.3 Patent Text mining for innovation methods

- Function-Oriented Search (FOS) [27, 35, 36]
- Function Behaviour State (FBS) [2, 37, 38]
- Contradictions and Principles [10, 14, 25, 29, 39]
- Design-by-Analogy [16, 31, 40, 41]
- Trends and Forecasting [11, 42, 43, 44]
- Open Innovation and technology Transfer [30, 42, 44, 45]

2 Method

The main tool for this research was PatentInspiration [46]. It has two main steps; firstly, to build a filter, and secondly to visualise the data. Building a filter means distilling, from the over 120 million patent documents, a list of several thousand relevant patent documents for analysis. The second part of the software allows us to visualise the data by slicing and dicing elements of it to depict meaningful graphic illustrations, X-Y's, maps, tables, text analysis or customised diagrams to interpret the patent data research pool.

3 Results and Discussion

3.1 WISH – Performance, Harm, Interface, Cost

Cost-benefit analysis was founded by Jules Dupuit in 1848 [47]. Later Genrich Altshuller [48] TRIZ founder, defined value as ideality being benefits over cost and harm. In 1997, Clayton Christenson’s acceptability model presented functionality, reliability, convenience and price [49] Adams [50] models sustainability into environmental, social and economic segments. An elaborated summation of value factors comes out of an unsuspected angle; software design. Its ISO/IEC 25010 (2011) defines an array of factors as quality requirements for systems and software engineering that give a great summation of the different elements of value. Finally Kurosu [52] offers a list of ‘*ilities*’ under the third factor. Table 1 shows an overview of the approaches over time.

Table 1. Approaches to value categorization [1].

Author	Equation	Factor 1	Factor 2	Factor3	Factor 4
Dupuit, J. (1848)	cost/benefit	benefit	---	---	cost
Altshuller, G (1984)	ideality	benefits	harm	---	cost
Shackel <i>et al</i> (1991)	acceptability	utility	---	use-, likability	cost
Christenson, C. (1997)	buying hierarchy	functionality	reliability	convenience	price
Adams, W.M. (2006)	sustainability	---	environmental	convenience	price
ISO/IEC 25010 (2011)	---	performance	safety, security	use-, portability	cost
Kurosu (2017)	---	performance	harm, safety	‘ilities	cost
Innovation Logic (2020)	Value	performance	harm	‘interface	cost

Category 1: Performance

The main approach to identify the performance is taking a verb” pattern in same sentence with toothbrush. A second approach is to use modifier pattern *increase noun.** As shown in Fig 1.A, the main function of a toothbrush patent is cleaning (blue). The inclusion of ‘brush head’ (red) in the word cloud is noise, as ‘brush’ can be interpreted as a verb, making the pattern an action brush a head rather than the noun brush head. Force and pressure (green) are performance overwrites.

Category2: Harm

Harm encompasses all elements in your solution that have a negative effect either to the users, the system or the environment. The textual patterns of harm elements in patent literature are nouns close to synonyms of remove*, avoid*, prevent* (* being any conjugation or ending). The pattern in Fig 1.B shows harm elements very specific to the teeth cleaning process. In this way the innovator can easily explore what he or she is or isn’t working on, and what other inventors are proposing as patent solutions.

Overwrites including environmentally friendly, pain, noise, problem, harm, fault, are shown in green. The pattern includes a second text group namely the adjectives ending with *less, *free e.g. germ-free. The term in term-free is often a harm that has been eliminated in the proposed patent. The result of a *-free pattern search is shown in Fig 1.C. A similar text pattern that can help to extract harm elements in a patent pool is *less, shown in Fig 7. Both *free and *less are related to the TRIZ ideality approach which claims: the ideal system is no system, but the function remains.



Fig. 1. Text pattern results A. Performance patterns B. Harm patterns C. *-free and D. *-less

Category 3: Interface



Fig. 2. Text pattern results E. Interface patterns F. Easy to verb:* G. *ility and H self-*

Convenience [49] concerns how the interaction ‘feels’ or interfaces with the solution. A more appropriate grouping for usability, learnability and portability, [51, 52] is the term ‘interface’, as this is wider than ‘convenience’. The textual patterns of ‘interface’ are *easy to verbs* * or text patterns with **ability*, **llity*, *self*.* and overwrites like *user-friendly*, *convenient*, *comfortable*. Fig 2.E depicts the textual pattern for interface. As the interface is all about making the user experience easier, a text pattern ‘easy to’ identifies elements of convenience, for example, easy to open, easy to apply, easy to brush, easy to operate, easy to adjust, easy to rinse, easy to store, easy to transport,

shown in Fig 2.F. A second valuable pattern is **bility*, commonly referred to as '*ilities*'. de Weck *et al.* [53] claim that *ilities* are properties of engineering systems that often manifest and determine value after a system is put into initial use (e.g. resilience, interoperability, flexibility) [54]. Rather than being primary functional requirements, these properties concern wider system impacts with respect to time and stakeholders. Over the past decade there has been increasing attention to ilities in industry, government and academia [53]. The ilities extracted in Fig 2.G show mainly parameters connected to the system usage, and therefore belonging to category 3 (light blue), with some terms belonging in the other categories (performance dark blue, harm green and cost red). As discussed in category 2, Fig 5 and 6, examples like hands-free and wireless belong in this category. The ideal easiness for the user (as referred to in Fig 2.E) ideally, is that no action is at all required, it is automatic. The system performs the function (main or sub) by itself. This is where the text pattern *self** and *self-** identifies ideal solutions. It is part of the creative process to look at all functions (mainly in category 1 and 3) whilst asking the question, can this *function X* be performed by itself. The pattern *self – function X* can be constructed. The patent database provides a good starting point (knowledge resource) for highlighting the sorts of '*self-X*' functions being achieved by other problem solvers. Examples of *self** solutions are given in Fig 2.H.

Category 4: Cost

Price [49] relates to financial value. However, the cost of a solution can include; cost to obtain, cost to run [52], cost of production etc. A more appropriate category name than price is 'cost'. It is economical innovation; adding value by reducing cost. The patterns are simply cost of noun:*** and ** cost* as depicted in Fig. 3.



Fig. 3. Text pattern cost of *** and ** cost*

3.2 SHOP –connecting solutions across domains

Shopping is creating an open innovation map. It is like asking the rest of the world what is known about one's research questions. Depending on the setup of the query, the map will explore the domains far from your known in-domain research approaches. Applied to our toothbrush examples, there are several ways to come up with the abstract terms defining the toothbrush or the cleaning teeth experience. Three distinct approaches will be demonstrated in this paper however there are more approaches [1]: 1. Functions 2. Problems and 3. Combination Analysis

1. Functional branch

Looking for clean teeth in a function database the effects for “clean solid”, bring 26 effects. Eleven effects -Acoustic Vibration, Cavitation, Ultrasonic Oscillation, Desorption, Electrolysis, Friction, Dissolution, Mechanical Action, Brushes, and Electrochemical- are also present in the patent pool of toothbrush. However the rest of the effects are not and therefore new potential ways to perform the function, they are shown in Fig 4 as “out of domain effects”.

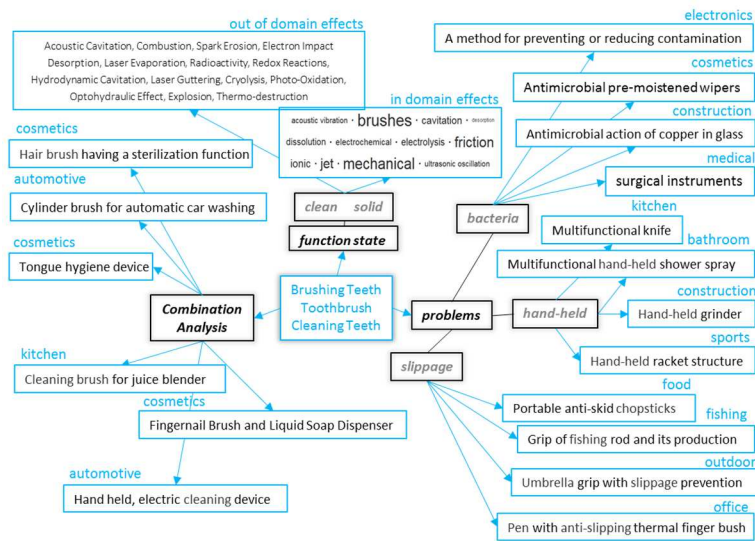


Fig. 4. Open innovation map (shop) for brushing teeth and toothbrush

2. Problems branch

Problems can be harvested from a text pattern as simple as *noun: *problem* or *verb: *problem* in Title Abstract, Claims and Description to generate the terms as shown in Fig 5.J. In relation to the value equation in, the problems are colour coded as; performance in grey, harm in green, interface in blue and cost in red. All problems are potentially an Abstraction to connect to other domains. To take some specific problems by means of example, take the problem of bacteria, the problem of gripping, holding or hand-held, and the slippage problem.

Bacteria

A filter is built with ‘kill bacteria’ in Title and Description and NOT toothbrush in Title or Abstract. The choice of Description is that the Description is often the place where the problems are described.

Hand-held

As a toothbrush is hand-held, it gives us an opportunity to mark this term as an Abstract connection to other hand-held products. The filter is built as ‘hand-held’ and

‘easy’ and ‘hold’ in Title Abstract and Claims. In this way, one can easily extract hand-held devices with a pattern ‘hand-held’ noun, as some examples given in Fig 5.K. below.



Fig. 5. Text pattern J. problems, K hand-held * and L slippage problem

Slippage problem

The filter is built with (*slippage OR 'anti-slip'*) AND *hold* in Title or Abstract. The *noun groups* in this filter can give a first indication of the other products with a slippage problem as shown in Fig 5.K.

In this way, all three problems (and any other problem of choice) can systematically be connected to out-of-domain solutions after which the patents can be explored for technology transfer. Fig 4 (right) gives an overview of the proposed problems arm of the open innovation map the donor domain being marked in blue connected to a series of out-of-domain solutions.

3. Combination Analysis branch

The combination analysis combines 10 terms that are specific to the toothbrush domain. This has the starting point of the whole patent database except the patents in the toothbrush filter. Taking the terms as *clean**, *brush**, *bacteria*, *antimicro**, *grip**, *slip**, *induct**, *identif**, *reach** and *rins** in Title, Abstract and Claims, give us a list of patents that have up to 7 of the 10 terms, and that are not in the toothbrush pool. The top (highest term matching) 790 patents were selected, to create a new filter that can be investigated for other domain solutions. From these actions, the final arm of the open innovation map can be constructed, the combination analysis arm, by selecting the relevant patents from different domains as shown in Fig 4. (right).

In conclusion, SHOP (Open Innovation mapping) is an important part of the patent driven Innovation Logic through both the proposed abstraction models and the direct connection to specific patent literature. The approach is structural and demonstrates a boost in creative thinking within the often constraint environment of engineering innovation.

3.4 CREATE –varying properties

The third step in Innovation Logic brings variation of properties for new or improved functions. A key finding of this research has been the correlation between properties and adjectives, and verbs and functions. Properties can be adjectives in patent literature. This allows us to distil a set of properties of any product by searching adjective:* product, as shown in Fig 7. M on toothbrush. This finding has shown progress in patent research in terms of what properties are patented, what properties are not patented or, what are the evolutions of patents in property variations in a certain product context? As shown in Fig 8 below, a variation in porosity, e.g. hollow, connects in patent claims to rinse, contain, store, etc. With an iterative use of Find Related Terms [46], a list of related terms can be identified, that is used synonymously with ‘hollow’ to complete an adequate list of adjectives for the purpose of studying the porosity spectrum. The adjectives list includes *empty, voided, unfilled, hollow, vacant, open, unoccupied, concave, porous, spongy, foam, tubular, cylindrical, cavity, interior, hole, tube-shaped, open, multi-hollow*. In order to build the connecting functions, a text pattern search in 26 025 patent documents with *hollow* in Title, *hollow to verb:** depicts the results in Fig 25, some verbs are selected below. From Fig 7. N an example list of verbs for Innovation Logic can be selected, they include *absorb, appear, assemble, break, contain, cool, drain, filter, fit, grip, hang, hold, identify, measure, stack, store and transport*. If one looks at applying any property change to a product, the system can be considered as a whole – hollow toothbrush, or any component or subsystem of the toothbrush.



Fig. 7. M. adjective:* toothbrush N hollow to verb:* and O hollow noun:*

Fig 7.O shows hollow components in the toothbrush patent pool. Ten other 10 property variations were similarly distilled in there adjective – verb, property – function relationships. They are *segmentation, surface, shape, flexibility, pulsation, state, integration, senses, transparency and automation*.

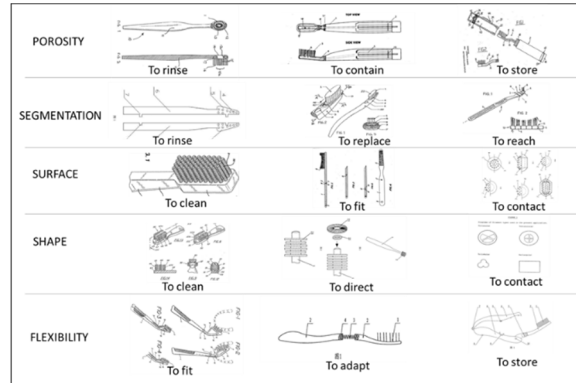


Fig. 8. Example property spectrum – function connections in toothbrush patents

In summary, property variation for new or improved function, is an idea exploration step within Innovation Logic. As demonstrated within the toothbrush case study, with a set of property spectra, that the property variations are present within patents and categorisable along eleven property spectra. The list of eleven is substantial and useful, but not a complete list. It is a general list that can be applied across domains. However, every system can have very specific properties, or functions, say digestibility in food and rolling resistance in tyres.

4 Conclusion

The language correlation in Wish (values), Shop (abstract problems) and Create (adjectives to properties) has been shown to be strong and easily applicable to mine patent literature for Innovation Logic. Being able to distil property-function relations across domains forms the backbone of this approach.

The main patterns to research the patent literature were identified as:

adjective noun:* to identify which type of property variations within which spectra is present in a specific patent pool

adjective to verb:* to connect properties to verbs that express a function in the system, and thereby connecting the property variation to a set of functions

adjective *ing and properties in adverbial adjectives that connect the improvement

adjective verb:* function by varying the action

Based on property-function relations that are present in products around us and, in cases, patents within the database of more than 100 million documents, the abstract framework can be applied to create the new, acting like a checklist for innovators across domains.

The language challenge is present, but as text analysis becomes stronger, specific relations can be distilled in more accurate ways. The inventor does not always use the correct language formulation, however, it is not the exception that makes or breaks the rule, here from an inspirational point of view, if there are enough inventions across domains that describe the property-function relation, they can act as triggers for the inventor to evaluate the change within their system.

In summary, it was shown that connections between the properties and functions are locked across domains, and can be expressed in adjectives and verbs. The domain context describes the system, the product, the process, component or article and is expressed in nouns.

Within the scope of this research, the system is limited to the quality of the patent literature, as supplied by the provider. Only certain parts of the patents are complete with full text in all fields, such as description or claims. Apart from the classical language analysis challenges such as homonyms, in science literature abbreviations, such as nm could stand for Nano meter (nm), but also Nano molar (nM), in chemistry, or Nautical mile (NM), a unit of length used for maritime and aviation purposes, or Newton metre (Nm), in physics. Most foreign patents have English translations. However, many of those are machine translated which is impacted by the limitations of the translation software. A substantial part of the patent database has no translation, which is a blind spot for the text analysis tools.

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