World Patent Information 45 (2016) 1–9

Contents lists available at ScienceDirect

World Patent Information

journal homepage: www.elsevier.com/locate/worpatin

Applying an anchor based patent mapping approach: Basic conception and the case of carbon fiber reinforcements

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ARTICLE INFO

Article history:
Received 6 July 2015
Received in revised form
7 January 2016
Accepted 9 March 2016
Available online 21 March 2016

Keywords:
Patent mapping
Visualization
Semantic analysis
Similarity measurement
Technological patterns
Carbon fiber reinforcement

ABSTRACT

Patent mapping is an important method for analyzing technological patterns both for scientific research and strategic tasks in companies. In this paper we focus on a specific type of technological pattern, namely the analysis of patents' positions in relation to predefined positions of application fields. For this purpose we use an anchoring approach. We apply semantic patent measurement and discuss RadViz as a powerful method to visualize the measurement's results and to provide insightful motion patterns for monitoring technology change. Moreover, we present an algorithm to define so called anchor points as high dimensional reference points by using textual elements of patents. By the example of carbon fiber reinforcements we demonstrate the usefulness of our approach. Thus, our approach enables academics to analyze important types of technological patterns like convergence or divergence by means of a new instrument and gives practitioners like the R&D management of companies the opportunity to build a reliable strategic business decision support.

1. Introduction

The strategic importance of monitoring technological change in today's fast changing environment is crucial to future success [1,2]. In this respect, a useful method in the broad spectrum of the patent analyses toolset is patent mapping [3–5]. It is applicable to discovering technological patterns both for scientific research and strategic tasks in companies [6,7]. For instance, recent publications based on patent mapping deal with scientometric questions. Most recently, Leydesdorff et al. [8] have developed overlay patent maps. They construct a base map to visualize technological fields (represented by IPC classes on a three or four digit level) with patent co-citations indicating similarities between these technological fields. They apply data from the United States Patent and Trademark Office (USPTO) and visualize it by means of a MDS-based software called VOSViewer. They combine this base map with an overlay map, indicating for instance the patent activities of an industry or company. Prior papers by Schoen et al. [9], Kay et al. [10] as well as Boyack and Klavans [11] use similar approaches based on different data or other visualization algorithms, especially network tools. In addition to scientific research there is a need for patent mapping in many organizations and companies, be it for the comparison with competitors [12], for patent infringement analyses in technical areas [13,14], for profiling a company's key inventors [15], or for profiling novelty in a technological field [16].

In contrast to the approaches mentioned in the context of scientific research which focus on the base mapping of technological fields and overlay different patent data, patent mapping for companies mainly focuses on the direct mapping of single patents, using different kinds of similarity measurements between them to generate a map. For instance, a company may want to know if another company aims to fence the company's patents (see Ref. [17] for different formations of fences); it may want to know if there are converging trends from or to a specific technology [18], etc.

To generalize these artefacts: In a patent map different kinds of objects may be presented and set in relationship to each other: patents, patent sets as collections of different patents, parts of patents such as key terms or additional information like technical dimensions as well as combinations of the introduced objects. Normally, for a patent map a two or three-dimensional diagram is used as a basis to position the objects. Traditionally, methods of multidimensional scaling, abbreviated MDS [19], or self-organizing maps, abbreviated SOM [20] are applied to construct such patent maps. This entails several shortcomings, one of them being the instability of the objects' positions when a patent map is generated more than once. We will go into detail regarding the shortcomings

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http://dx.doi.org/10.1016/j.wpi.2016.03.005

of traditional patent maps in Section 2.

In the following we suggest a new method for overcoming particularly the drawback of the instability of traditional patent maps. In more detail we pose as research questions: How can technologies in a technological field be represented by means of semantic anchor points? How can these anchor points be used to position a set of patents in a stable way? How can specific effects like technological change (e.g. convergence) be identified in this setting? To answer these questions, we present an anchor based approach, using an algorithm called RadViz in Section 3, which has already been used successfully in other fields of science. To apply this algorithm for patent mapping some design decisions have to be made and a specific process has to be developed which is outlined in Section 4. By means of a case study from the technological field of carbon fiber reinforcements we illustrate the use and benefits of our approach in Section 5. In the conclusions we point out some limitations of our approach, especially in comparison with conventional methods of patent mapping in Section 6. This eventually leads up to perspectives and ideas for future research.

2. Conventional methods for patent maps and their shortcomings

By use of a patent map, analysts should be able to identify relationships such as distances between the objects mentioned above or clusters in an intuitively visual manner [7]. Patent maps normally build on data matrices that collect information regarding distances between all possible pairs of objects. These distances may be measured in different ways and should represent some kind of similarity between the objects, e.g. a similarity of concepts, a similarity of application fields, a similarity of manufacturing, a similarity of functions ([21] for types of similarities). Traditionally, the methods of multidimensional scaling or self-organizing maps are applied to construct such patent maps. Patent maps as they are used today and their construction have some major shortcomings:

(1) As mentioned before, the data source of a patent map is a data matrix which is normally symmetrical. If patent maps are generated more than once from one identical data matrix by means of traditional methods, the respective maps usually look different, and the positions of the objects change from map to map. This could lead to different cluster formations that might produce different implications for the analysts. The reason for this disadvantage can be found in the applied methods (i.e. the multidimensional scaling or in the self-organizing map) which actually reduce the dimensions of the data in the data matrix. In both methods minor errors are accepted considering mathematical restrictions; the errors are measured in one or more stress variables [22,23]. This is normally done in two steps: First, the method positions the objects in the diagram, generating an initial configuration, and then it tries to improve the configuration in an interactive way until a termination criterion is reached.

(2) At times it is useful for a patent analysis to select only parts of the original set of patents and to visualize this part (sub patent map). For instance, there could be a selection taken from the original set of patents according to inventors, applicants, application years, grant years, or other criteria. In such sub patent maps different visualizations with different structures may occur compared with the original patent map. This may lead to inconsistencies of perceptions and evaluations by the patent analysts.

(3) At times it is useful for a patent analysis to construct a patent map stepwise, i.e. starting with a sub patent map, then proceeding step by step to the full patent map. In such a case the drawback that has already been mentioned under point number two may occur in an even more pronounced way. After adding an object, the configuration of the patent map may change fundamentally. Again, this may lead to inconsistencies of perceptions and evaluations by the patent analysts.

(4) At times it is useful for a patent analysis to supplement the patent map with additional useful information, for instance information concerning the technological field for which the patent analysis should be carried out. Conventionally this is reached by post processing of the patent map in a separate software application which is not only time-consuming but may also be influenced by the producer in an unwanted way.

To sum up: There is a need for a method that generates stable positions of the objects placed in a patent map (e.g. for anticipating technological convergence). We do not suggest such a method for all technological patterns that can be analyzed by patent mapping, but for analyzing positions of patents in relation to predefined positions of application fields.

3. Selecting RadViz as an anchor based approach in general

To address the need explained above, we screened several methods and identified RadViz as an algorithm with great potential. Soukup and Davidson [24] already recognized an increasing necessity of visual data mining and claimed that “visualization is a key in assisting business and data analysis to discover new patterns and trends in their business data sets” [24]. RadViz is short for “radial coordinate visualization” and has been used in prior art to determine relations and trends among data, especially in the field of computer science, mathematics, biochemistry and genetics [25–28]. In this paper we outline a novel approach by using RadViz for patent analysis. Since it was designed to map multidimensional data to a planar picture on the basis of Hooke's law [29,30], the main advantage of this algorithm is that it needs no projections and provides a global view on the data set [31]. Sharko et al. [28] pointed out that RadViz is powerful in fuzzy clustering since it “[…] generates a continuum that provides more information on the relationships of records to each other than only the maximum association is used for each record” [28].

In RadViz, mapping points from n-dimensional space in a plane is clearly defined by position of the corresponding n anchors, which are set in a circle. Considering a point $[y_1,\ldots,y_n]$ from n-dimensional space, this point is mapped as a single point u in the plane of anchors as follows: “[…] for each anchor j the stiffness of its spring is set to y_j and Hooke's law of mechanics is used to find the point u, where all the spring's forces reach equilibrium (they sum 0)” [26]. Therefore the point $u = [u_1, u_2]$ is mapped with the following coordinates:

$$u_1 = \frac{\sum_{j=1}^{n} y1\ \cos(\alpha j)}{\sum_{j=1}^{n} yj} \quad (1)$$

$$u_2 = \frac{\sum_{j=1}^{n} y1\ \sin(\alpha j)}{\sum_{j=1}^{n} yj} \quad (2)$$

For an application of RadViz, the data should be within an interval between zero and one [26,32]. If necessary, normalization can help to achieve this.

In order to simplify the explanation and the interpretation of a RadViz diagram, Novakova et al. [26] considered the case in Fig. 1, where the corresponding angles of the anchors a, b, c and d are $\alpha = 0,\ \beta = \pi,\ \gamma = \frac{\pi}{2}$ and $\delta = \frac{3\pi}{2}$. Applying these values in the Equations (1) and (2), the point $u = [u_1, u_2]$ is defined as follows: