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TRIZ REVERSE – SPECIFICATION AND APPLICATION OF A 7 STEP-BY-STEP APPROACH FOR SYSTEMATIC KNOWLEDGE AND TECHNOLOGY TRANSFER

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Abstract

A reverse inventing method for knowledge and technology transfer called TRIZ Reverse has been recently further developed by the HTW Dresden. The following paper presents this new methodology approach, which is based on the theory of inventive problem solving TRIZ. A comprehensive case study, e.g. patent analysis with the aim of alternative industry application identification, is conducted to specify and operationalize the single process steps involved. On this basis, the authors express their recommendations towards the desired and possible evolvement of TRIZ Reverse as a tool for innovation acceleration as well as their aims with regards to the exploitation of the selected patent.

Keywords: *TRIZ, TRIZ Reverse, Reverse Inventing, Reverse Engineering, Knowledge and Technology Transfer, Systematic Invention and Innovation, 7-Step-Approach, Patent Analysis*

1 Introduction

In the year 2019, Germany was one of the countries with the highest number of patent applications with a total of 178,184 filings [1]. Looking at this number it would be easy to assume that German inventors are successfully transferring their protected innovative theoretical knowledge and ideas into promising, market fitting products and services. Unfortunately, this assumption does not mirror the current situation. The German Patent and Trade Mark Office estimates that "in fact only three to five percent of the patents applied for lead to economic benefits income and thus meet the expectations of the applicants" [2].

On the one hand, this is a serious issue, since it reveals that the resources invested into the development and protection of intellectual property do not provide a certainty for the realization of viable products or services. On the other hand, the status quo offers a huge profit gen-eration improvement opportunity for inventors, innovation managers and technology transfer experts. In this regard, the Institute of German Economy (IW) estimates that "the German economy is sitting on unrealized assets of at least eight billion euros" [3]. The development of a systematic technology transfer method as a tool for the amplification of potentially expected Return on Investment (ROI), e.g. in R&D activities, is therefore highly desirable.

In this paper, we will briefly describe the fundamentals of the TIRZ Reverse approach. Based on a review of existing methods and algorithms in this field, in our study we developed a 7-Step procedure for a structured TRIZ Reverse process. This process has been developed alongside a concrete case study concerning a patent issued by HTW Dresden in 2019.

2 From TRIZ to TRIZ Reverse

2.1 Theoretical Basis

The aim of the Theory of Inventive Problem Solving (TRIZ) is to systematize the creative idea generation process, largely exclude chance, and to shorten the time resource required to come up with inventions [2]. Meanwhile the TRIZ method has been known in the western hemisphere for more than 30 years. It is being continuously developed and refined by various research facilities and institutes, i.e. TRIZ-fest. The research focuses primarily on the transfer to non-technical areas like service and support, as well as the connection with other methods in product development, such as QFD and FMEA [4]. The expansion of TRIZ to include new areas of knowledge, such as biology and psychology, is also being examined [5].

Additionally, the use of TRIZ for the identification of application areas for existing technical "solutions" has hardly been considered so far. A TRIZ Reverse method, which methodically supports the finding of application areas for already existing technical "solutions", would therefore be indeed desirable. It would not only facilitate the (knowledge) transfer into practice for universities and research institutions, albeit also significantly accelerate this process. From a scientific point of view, the specific question arises as to whether TRIZ's problem-solving process is generally reversible. According to the motto "solution seeks problem", new potential applications, i.e. problem areas, should be identified based on a known technical solution.

Current research results indicate that this possibility exists in principle, and that (generic) exploitation principles can be extracted. This primarily relates to the use and/ or sale of patents. Authors in current literature often speak of “reverse inventing” or “reverse engineering” when it comes to opening up new markets and/ or target groups for existing products or (technical) solutions [6]. While conventional market research instruments mainly rely on direct questioning and observation of potential customers, reverse inventing methods prefer to use abstraction. The strengths of the company or the products/ services are translated into abstract descriptions. The vocabulary used in the patent literature serves as a reference or frame of reference.

2.2 General Approaches

There are several suggested procedures in the literature for using TRIZ Reverse. More than 10 years ago, Darrell Mann [7] proposed a “principles-based patent search”. It contains step-by-step instructions to link search terms from patent databases with the inventive principles from Genrich Altshuller’s contradiction matrix. The greatest challenge faced, is the semantics used in the reference documents, since in today's patent specifications - not infrequently for legal reasons - different terms are used in comparison to Altshuller’s time.

To overcome this dilemma, Mann et al. (2006) developed a keyword catalog for all 40 inventive principles. Once the relevant inventive principles for a given technical solution are assigned, the key words can be used to search specifically in relevant patent databases. It is relatively easy to identify “patent clusters” or “areas of technology”, in which a relatively large number of patents exist that are related to the innovation principle sought. The International Patent Classification (IPC) codes (or classes) with which the technical contents of patents have been uniformly classified into 8 main groups worldwide since 1971 are the basis for clustering [8], [9].

During the past decade, several proposals of the TRIZ Reverse methodology were introduced. Depending on the objective and focus of the investigation, the algorithms are comprised of four to eight steps that the user must pass through in order to find suitable new areas of

application [6], [10], [11], [12]. A main distinguishing feature is the use of the contradiction matrix. In essence, this concerns the question of whether the 40 inventive principles including or excluding the 39 technical parameters are to be used for reverse inventing. From a methodological point of view, the use of the technical parameters should be aimed for, since in this way the examination scope for the patent search is restricted more effectively.

2.3 Common Barriers

Since the literature meanwhile contains several proposals for potential TRIZ Reverse methodological approaches, it is questionable, why the use of this approach has not yet become "mainstream" in most organizations, universities and research institutes.

One possible answer is that important figures in companies (c-suite members) are simply not aware of the various TRIZ Reverse methods for knowledge and technology transfer, and do not therefore not insist on the application when it comes to innovation processes. Another reason might be that the numerous potential benefits arising out of the incorporation of such a reverse invention method, e.g. portfolio expansion, ROI and/ or resilience increase in general, are not understood or not trusted yet due to the lack of experience and expertise.

In this regard, the question arises if the development of more comprehensive software tools to support the users might be what is still missing when it comes to supporting them in the process of the identification of suitable additional fields of application. Compared to the classic TRIZ, the presently available selection of professional software solutions using a TRIZ Reverse is significantly smaller. PIFURRA is one example, and the result of a PATE project funded by the DFG to improve and accelerate technology transfer in connection with the use of "adaptive surfaces for high-temperature applications" [13]. The software supports the automated assignment of relevant (scientific) publications to corresponding search requests.

3 TRIZ Reverse Procedure

3.1 6-Step Procedure by Glaser and Miecznik (Status quo)

One of the currently most elaborated on TRIZ Reverse methods, was proposed by Glaser and Miecznik in 2009. It was developed as a part of a collaborative case study with the German electronics company Wittenstein SE. The aim was to identify additional business opportunities for "a system for the controlled prolongation of limbs by means of a dynamic intermodular nail for implantation into the bone marrow of limbs, typically legs" in order to increase the revenue generated and boost the market growth potential [6]. The researchers have defined their version of the TRIZ Reverse inventive process in six steps as demonstrated in Figure 1.

One year later, Bianchi et al. [11] have developed a TRIZ Reverse methodology based on the work of Glaser and Miecznik. The aim of the research team was to support small- and medium-sized enterprises (SMEs) in finding alternative technology applications (ATA) in a more efficient way. Their process starts with a definition of the technology's requirements followed by a TRIZ-based analysis of the very same. Afterwards abstract problems are selected and ATAs identified. The last step of Bianchi et al.'s method is the creation of a strategic positioning matrix for the selected results.

In 2020, the researchers of the current paper have developed an advanced algorithm as part of a case study on the research of potential alternative use cases for a patent of a collagen based composite material, invented by the Faculty of Ecology at HTW Dresden.

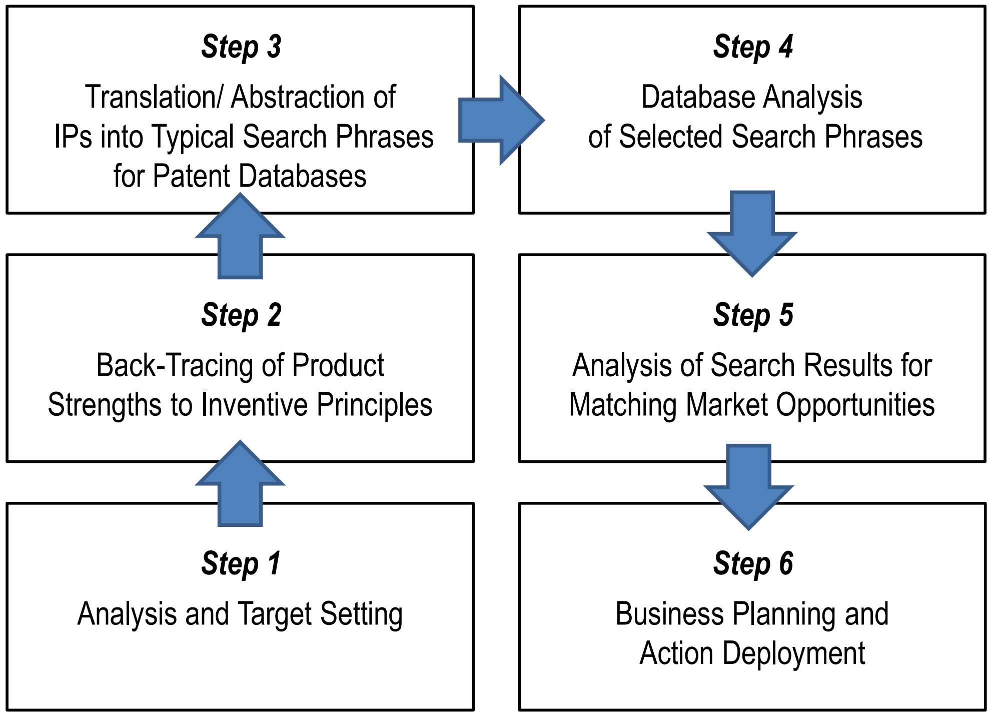

Fig. 1. TRIZ Reverse methodology approach in six steps by Glaser and Miecznik [6]

3.2 Advanced 7- Step Procedure by HTW Dresden

Step 1: Selection of a suitable invention (patent)

The initial step of the methodology is to conduct a research on appropriate patents. The researchers suggest using personal or professional contacts (network) with the objective to inform oneself on relevant inventions. Another option to gather information is to contact universities, companies or even private persons, who are involved in the area of intellectual property creation or management.

Step 2: Patent analysis and identification of relevant inventive principles

After an appropriate intellectual property has been selected, the next step is to analyze the full patent text and identify the most relevant inventive principles. The person in charge should search for key words which indicate technical solutions according to the 39 parameters of the TRIZ contradiction matrix. First of all, the technical solutions must be found which are improved by the invention, e.g. the new solution increases the speed of production. Afterwards, such technical solutions must be spotted which indicate that at least one parameter is limited with regards to unwanted change, e.g. the invention might limit the use of energy resources.

The identified technical parameters have to be inserted into the inventive principle identification and prioritization matrix (IPIP matrix) – a tool based on the classic TRIZ contradiction matrix built for the acceleration of the inventive principle discovery procedure. It includes a focused contradiction matrix field, which delivers results for inventive principles for technical parameter contradictions, a field for calculation of the appearance of inventive principle's numbers, and a summary column delivering the sum of all the appearances of an inventive principle by taking all contradiction pairs into consideration.

Step 3: Key word selection and search code creation

In this step the identified inventive principles have to be "translated" into the vocabulary used in the common language in patent texts. For this purpose the key word approach for assigning terms to the single inventive principles as proposed by Mann [7] is applied. Moreover the researchers have decided that it is necessary to introduce key words from the patent text itself into the search code used for the database research. The most frequently used terms in any text can be quickly identified by copying the desired text and pasting it into a word density analyzation tool.

In this context, the application of a systematic approach for code creation is suggested, which shall be tested in the upcoming step. This system should prevent the incorporation of trial and error practices, and increases the efficiency of the whole process. Overall, the code consists first and foremost of key words from the patent text with the highest frequency of use as well as such terms which are related to the 40 inventive principles of TRIZ and the operators applied at the relevant database (e.g. AND, OR etc.). With the search code template created in Excel $16 \cdot 12 = 192$ different search code variations can be created.

Step 4: Database research (search code testing)

The aim of step 4 is to identify the best matching patent hit lists by systematically testing the search codes created in step 3 in a patent database, e.g. dpma.de. The authors suggest to look for hit lists containing between 100 and 500 (+/-10) patents. A similar recommendation is provided by Glaser and Miecznik [6] and Günther [14].

To find such hit lists, it is best to maintain a systematic approach with the code testing, so that a better overview can be obtained. If the time is limited, then the introduction of the "AND" instead of the "OR" operator in the search codes used might be necessary in multiple places. After at least one hit list with an appropriate number of patents has been identified, the analyst may proceed to the next step.

Step 5: Semi-automated patent list analysis

For the efficient analysis of the identified hit list, an automated IPC code identification matrix – including a systematic color code scheme to facilitate the readability of the results – has been created with the support of Excel. To take full advantage of the automation system, the authors of the current paper suggest following these four steps:

1. Download the patent list (with 100 to 500, +/-10 results) in an Excel spreadsheet from DPMA platform by using the expert search mode.
2. The file will likely be in ".xls" format. Make sure to save the Excel file once again under the more up-to-date format ".xlsx".
3. Copy and paste the semi-automated patent list analysis template starting exactly in the specified cell in the new file to ensure functions and links.
4. Visualization tools are included in the Excel file to display the preliminary results of the analysis, e.g. bar chart. A reselection of the area is necessary.

Step 6: Manual patent list analysis (3 stages)

The manual in-depth analysis shall continue with a review of the preliminary results from step 5. A focused analysis is further performed on one (or as many as desired) selected IPC codes of second level hierarchy (e.g. H01). In this context, the IPC codes of second hierarchy level with the most occurrences are selected, and from there on the IPC codes of third level hierarchy (e.g. H01L) with preferably five or more patents included identified by color coding. All relevant patent clusters (in full line, i.e. with all the information provided by the patent database) have to be copied and pasted into a new Excel sheet for the purpose of organization.

After aligning the data and shifting several columns, the titles of the columns in the final Excel spreadsheet are as follows: Release date, IPC main class, IPC minor/index classes, Common Patent Classi-fication (CPC), Reclassified IPC (MCD), Test substance, IPC, Inventor, Applicant/ Owner, Product, Process, Country, Entity, Industry, Contact, Title, Patent Plot, Summary, 1. Page, Complete Document, Sequence listing URL, and Searchable text URL.

Not all necessary information is provided by the patent research database, i.e. Country, Entity, Industry, Contact and Patent Plot. Therefore, the final task in step 6 is to gather these facts or data via Internet research or other tools for information gathering. For the column Patent Plot, selected parts from the first paragraphs of the full patent text description may be used. Another part to carefully review in the search for potentially appropriate text passages is the patent claims section.

Step 7: Discussion of possible cooperation and patent exploitation opportunities

The final step of the advanced TRIZ Reverse method is the presentation of the results to the client, which includes the discussion of any further steps of the technology transfer process. The authors suggest starting the presentation by revealing the most outstanding findings, which could be for example huge patent clusters in specific or unexpected areas. In conclusion, it should be noted that the decision for future executive steps in terms of cooperation or product development should not be made without careful consideration of the current market status or a market trend analysis [11].

4 Application of the HTW Dresden Procedure

4.1 Case Study Introduction

For the purpose of the development of the TRIZ Reverse methodology and the identification of alternative application fields of an already protected technology, a HTW Dresden owned patent [15] in the area of medicine (IPC main class: A61L 27/44) has been selected. The full title of the patent is “Biocompatible molded part and process for the production of a collagen-based layer material“. A simplified illustration of the process (patent code DE102017123891) can be seen in Figure 2.

A short fragment of the patent text shall provide a brief understanding of the new technology: “A method for providing a collagen-based layer material (3), comprising the following steps: - providing at least one swellable collagen material (1), - contacting the swellable collagen material (1) with an aqueous solution so that the swellable collagen material (1) can swell, arranging the swollen collagen material (1) in layers so that a layer arrangement (2) with at least two layers (1.1 to 1.5) lying on top of one another at least in some areas is formed, and air-drying the layer arrangement (2) at a temperature below 50 ° C, whereby the superficially adjacent layers (1.1 to 1.5) are crosslinked with one another.” [15].

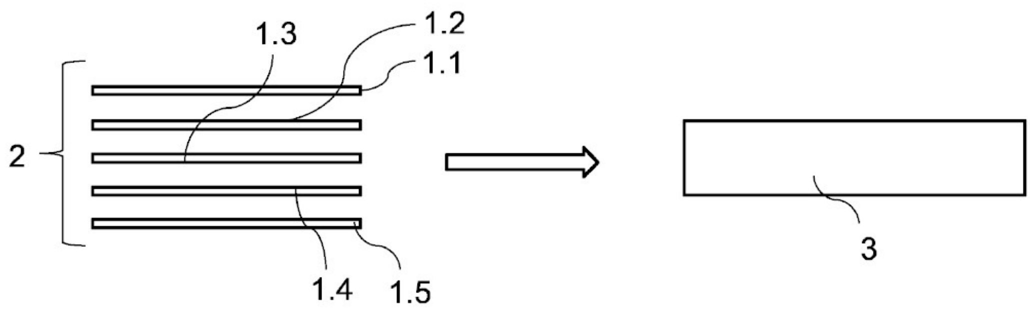

Fig. 2. Patent DE102017123891 (invention 1) [15]

4.2 Step-by-Step Approach

In this chapter the analysis of the previously introduced patent is presented according to the 7-Step TRIZ Reverse procedure developed by the HTW Dresden (see chapter 3.2).

Step 1: Selection of a suitable invention (patent)

The patent selected for the analysis was discovered within the scientific network community of the university, hence through cross-faculty networking endeavors including members of the Faculty of Ecology and the Faculty of Business Administration. The initial input was provided by the vice president´s office for knowledge and technology transfer.

Step 2: Patent analysis and identification of relevant inventive principles

After reading the full patent text and pointing out, as well as inserting the relevant key words in the IPIP matrix, the top three inventive principles – (35) Parameter changes (13 points), (1) Segmentation (10 points) and (40) Composite materials (7 points) – have been identified. A screenshot of the applied Excel spreadsheet is depicted in Figure 3.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	PA (KBSM) collagen-based layer material	(1) Weight of a moving object				(7) Volume of a moving object				(13) Stability of an object				
2	Undesired change:													
3	(11) Pressure or tension	10	36	37	40	6	35	36	37	2	35	40		
4	(12) Shape	10	14	35	40	1	15	29	4	22	1	18	4	
5	(13) Stability of an object	1	35	19	39	28	10	1	39					
6	(15) Durability of a moving object	5	34	31	35	6	35	4		13	27	10	35	
7	(17) Temperature	6	29	4	38	34	39	10	18	35	1	32		
8	(27) Reliability	1	3	11	27	14	1	40	11					
9	(31) Negative side effects of the object	22	35	31	39	17	2	40	1	35	40	27	39	
10	(32) Ease of manufacture	27	28	1	36	29	1	40		35	39			
11	(33) Ease of use	35	3	2	24	15	13	30	12	32	35	30		
12														
13	Innovation principles (IPs)													
14	1. Segmentation	3				5				2				10
15	2. Separation	1				1				1				3
16	3. Local quality	2				0				0				2
17	4. Asymmetry	1				2				1				4

Fig. 3. Inventive principle identification and prioritization matrix (IPIP matrix)

Step 3: Key word selection and search code creation

In this part of the process, the authors have created a huge variety of suitable search codes for a further testing session on the patent database DPMA. The task has been performed by using key words related to the previously determined relevant inventive principles as suggested by Mann [7] as well as an open-source word density analysis tool [16] in order to discover the five most frequently used terms in the patent text. In this case the most frequently used terms were: “Schichtanordnung”, “Schichten”, “Schichtmaterial”, “Verfahren” and “Kollagenmaterial”.

Step 4: Database research (search code testing)

Subsequent to performing the elaborate testing process with the formerly created search codes, the decision had been made to proceed with analyzing the code, which has contributed to the localization of the hit list with the highest acceptable number of patents.

The following search code supported the identification of the relevant outcome and led to 511 hits: BI=(Schichtanordnung UND Schichten ODER Sichtmaterial ODER Verfahren UND Kollagenmaterial) UND BI=(Eigenschaft? UND Druck? ODER Temperatur? UND Dichte?) UND BI= (segmentieren ODER zerlegen ODER teilen) UND BI= (Verbund? ODER Verbindung?). The standardized search code is: S6.7 (1001)-101-00-0.

Step 5: Semi-automated patent list analysis

After downloading and inserting the relevant hit list into the semi-automated patent list analysis tool - starting from line 520 in the Excel file - the most prominent IPC sectors (also IPC main classes or industries) were immediately revealed to be B, G and H. Furthermore, some other smaller potentially relevant patent clusters were localized in sectors A and C. The bar chart in Figure 4 shows the search results of the case study “biocompatible material”.

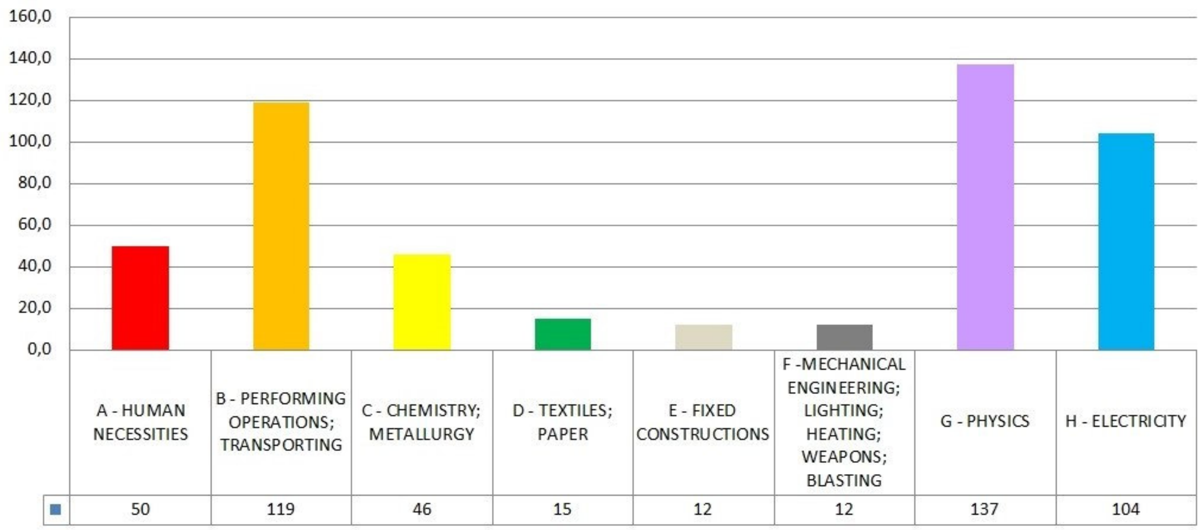

Fig. 4. Semi-automated analysis tool – hit list results from search code S6.7 (1001)-101-00-0

Step 6: Manual patent list analysis (3 stages)

In the fifth patent analysis step of the procedure, the most relevant IPC main classes were revealed by using the incorporated count function of the semi-automated analysis in Excel.

The current sixth step included a manual analysis in three stages focusing on the sectors A, B, C, E, G and H, which contained the most patent clusters (with more than five patents of one IPC class) in the selected hit list. The in-depth analysis revealed the largest patent clusters in the semiconductor industry (IPC class H01L). Further large patent agglomerations were recognized in the areas of photosensitive materials (G03C), electrography (G03G), layered products (B32B), printing (B41M), implantable filters (A61F), separation (B01D), containers for storage (B65D) and processes or means (H01M).

The relevant patent clusters identified – applying the previously defined color code for the respective sectors – can be seen in Figure 5.

IPC?	#	
H01L	64	SEMICONDUCTOR DEVICES; ELECTRIC SOLID STATE DEVICES NOT OTHERWISE PROVIDED FOR
G03C	40	PHOTOSENSITIVE MATERIALS FOR PHOTOGRAPHIC PURPOSES; PHOTOGRAPHIC PROCESSES, e.g. CINE, X-RAY
G03G	33	ELECTROGRAPHY; ELECTROPHOTOGRAPHY; MAGNETOGRAPHY
B32B	23	LAYERED PRODUCTS, i.e. PRODUCTS BUILT-UP OF STRATA OF FLAT OR NON-FLAT, e.g. CELLULAR OR HONEYCOMB
B41M	19	PRINTING, DUPLICATING, MARKING, OR COPYING PROCESSES; COLOUR PRINTING
A61F	15	FILTERS IMPLANTABLE INTO BLOOD VESSELS; PROSTHESES
B01D	13	SEPARATION (separating solids from solids by wet methods B03B, B03D, by pneumatic jigs or tables B03B)
B65D	12	CONTAINERS FOR STORAGE OR TRANSPORT OF ARTICLES OR MATERIALS, e.g. BAGS, BARRELS, BOTTLES, BOXES, CANS
H01M	12	PROCESSES OR MEANS, e.g. BATTERIES, FOR THE DIRECT CONVERSION OF CHEMICAL ENERGY INTO ELECTRICAL ENERGY
A61K	9	PREPARATIONS FOR MEDICAL, DENTAL, OR TOILET PURPOSES
C08G	9	MACROMOLECULAR COMPOUNDS OBTAINED OTHER THAN BY REACTIONS ONLY INVOLVING CARBON-TO-CARBON BONDS
A61B	8	DIAGNOSIS; SURGERY; IDENTIFICATION (analysing biological material G01N, e.g. G01N 33/48)
B42D	8	BOOKS; BOOK COVERS; LOOSE LEAVES; PRINTED MATTER CHARACTERISED BY IDENTIFICATION OR SECURITY FEATURES
E04B	8	GENERAL BUILDING CONSTRUCTIONS; WALLS, e.g. PARTITIONS; ROOFS; FLOORS; CEILINGS; INSULATION

Fig. 5. IPC class in-depth analysis - results from search code S6.7 (1001)-101-00-0

Step 7: Discussion of possible cooperation and patent exploitation opportunities

The team is currently analyzing market entry and expansion opportunities based on the outcomes of the patent analysis. Cooperation options with industry partners in the area of packaging (part of sector B) are in the stage of negotiation. The future executive steps need to be carefully considered. For the time being, the objective is either to set up a licensing plan i.e. aim for a cooperative business contract or to actively support a successful spin-off based on the protected technology.

4.3 Results and Findings

The case study performed using the new TRIZ Reverse method for systematic invention, as well as knowledge and technology transfer, has revealed a multitude of unexpected alternative areas of potential business ventures. Most of all the researchers were surprised by the occurrence of huge patent clusters – hence development opportunities - in the industries of semiconductors (H01L), construction (E04B) and container/storage/transport (B65D). Even though the identified results are promising, the authors' opinion is that there is still work ahead of the team until first tangible evidence can be provided in terms of successful product development and large-scale entry of at least one desired target market. When it comes to the process itself, the group has achieved a remarkable increase in the degree of automatization of the analysis procedure of relevant patent texts. Nevertheless, the research team aims to further increase the efficiency, data recognition and handling accuracy of the tools utilized.

Given the recent results and findings of the patent analysis performed, the research group has made the decision to actively pursue diverse options of accelerating the process of product development and market entry. Meanwhile, a very important cooperation partner has been found as a promoter for the validation funding for the exploitation of the currently selected patent. The team is looking forward to working together with this industry partner and to contributing to a successful transfer of knowledge and technology. Additionally, public funding by the Federal State of Saxony was granted to accelerate the transfer of project results.

5 Conclusions

The authors have recognized that the newly developed TRIZ Reverse method offers a lot of possibilities to facilitate the knowledge and technology transfer process. However, a variety of improvement suggestions are proposed by the researchers.

First of all, the technical parameter identification process in the second step could be accelerated by the incorporation of comprehensive text analysis software, programmed to target specific terms. Secondly, the function of the IPIP matrix needs to be further automatized in terms of gathering the inventive principle data immediately from an online or offline source. Thirdly, this tool could be further developed to generate the connected key words necessary for the subsequent search code generation. Moreover, the search code template used could be analyzed with the help of empirical research with the aim to identify if there are logic gate combinations, which are generally applicable for finding fitting patent hit lists.

Furthermore, the authors' overall future aim is to contribute to the establishment of a wide user base for this newly developed methodology. A semi-automated patent list analysis – actually performed by Excel – could be potentially evolved to a state of full-automation. In order for this to gradually happen, the team is currently discussing diverse options for the holistic improvement of the methodology and its toolkit – in particular the enhancement of the user friendliness of all elements incorporated in a professional software tool.

Reflecting on how these improvements could be implemented, the cooperation with programming experts in the field of artificial intelligence (AI) at the HTW Dresden, or at other partner universities and/or organizations, has been identified as a viable option. The jointly developed method and its tools would enable the increase of not only the speed of text analysis, but also (potentially) enable an accurate data harvesting process. This in turn would facilitate the interpretation of the results generated.

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