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- Promotion of research and development on organization of innovation knowledge in general and particular fields by integrating conceptual approaches to classification developed by artificial intelligence and knowledge management communities,
- International observation, analysis, evaluation and reporting of progress in these directions,
- Promotion on an international level of the exchange of information and experience in the Theory of Inventive Problem Solving TRIZ of scientists and practitioners, of universities and other educational organizations,
- Development of TRIZ through contributions from dedicated experts and specialists in particular areas of expertise.

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Dynamic and Semantic Database of Effects for Technology Transfer

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Abstract

A dynamic and semantic database of effects has been developed. Scientific effects databases are collections of effects that can be used in technology transfer for identifying alternative way to perform a same function. Usually effects consists in static lists that searchers have to manually browse imagining which effects are useful for their applications. In TRIZ community, more advanced tools (function-oriented), as the pointer to effects, have been developed. These tools link physical effects to a narrow set of functions contained in the database. These functions not always match perfectly the function required by searchers and in some cases the matching is inexistent. Another drawback is that also these databases are static. Indeed, the links between effects and functions are defined a priori and they are independent from the application field in order to gain a general validity. Pre-defined links can lead to the suggestions of physical effect unusable for a specific field or in the worst cases usable effects can be missing.
To overcome limitations, the authors have developed a dynamic pointer to physical effects that integrates a new library of effects and a semantic search engine called Kompat. It works with any function (pair verb-object). The link between function and physical effect is created by searching on technical or scientific literature, such as patents. The semantic engine automatically extracts all documents containing the physical effect to perform the selected function, and create a list of Effects linked to the initial function. The number of documents is also an index of the feasibility and the degree of maturity of the technology using that effect. Technology transfer is done comparing the list of effects already extracted in our initial search domain, with effects coming from a larger pool of documents; these effects are not yet known in starting domain but already used in others for performing the same function.
This article presents an application of the proposed dynamic effects database to a case study of eye inspection with the goal of identifying new promising technologies for measuring the temperature of the cornea.

Keywords: Technology transfer, effects database, patent, TRIZ, semantic search

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Nomenclature

CPC	cooperative patent classification
O	object
PE	physical effect
TT	technology transfer
V	verb

1. Introduction

Nowadays, Technology Transfer is an increasingly present activity, as confirmed by the interest of European commission [1] and also well-known patent offices such as the World Intellectual Property Organization (WIPO). In particular, WIPO provides numerous technology transfer webpages [2] and landscape reports [3] that present state-of-the-art search for relevant technologies in areas of particular interest such as public health, food security, climate change and environment. The growth of TT practices is also confirmed with the dynamic laws of evolution identified by Altshuller [4], that we report in the following:

Transition from macro to micro level

The development of working organs proceeds at first on a macro and then a micro level. The transition from macro to micro level is one of the main (if not the main) tendency of the development of modern technical systems. Therefore, in *studying the solution of inventive problems, special attention should be paid to examine the "macro to micro transition" and the physical effects, which have brought this transition about.*

Increasing the S-Field involvement

Non-S-field systems evolve to S-field systems. Within the class of S-field systems, the fields evolve from mechanical fields to electro-magnetic fields. The dispersion of substances in the S-fields increases. The number of links in the F-fields increases, and the responsiveness of the whole system tends to increase."

According to these laws of evolution, technical systems evolve integrating more S-field interactions, which implies that different technologies work together for achieving the same goal and they can be replaced according to the transition from macro to micro-level.

Among all the strategies for making technology transfer one of the most promising is based on patent search. Typically, searchers use the traditional patent search methodology that is an iterative process combining keywords and patent classes and in some cases inventors, applicants and backward-forward citations. In particular, the European Patent Office (EPO) proposes a patent search procedure based on three steps for searching prior art technologies:

1. Finding the right keywords: think of search terms which better describe your idea;
2. Product searching: find out what is already on the market that is similar to your idea (prior art) and that solves the same problem (competing art);
3. Patent searching: combine keyword and patent classification search.

The main limitations of this approach is that searchers have to be experts in patent search to choose the right keywords and patent classes and they have to know the technology before starting to search for it. These drawbacks make more complex and time consuming the patent search.

In TRIZ community, radically different approaches based on the functional search have been developed for supporting technology transfer. An excellent integration of the functional search (Action + Object) with physical [5-8], chemical [9] and geometrical [10] effects, is a tool called Pointers to Effects. It was introduced in the problem solving process by Altshuller [4]. He studied the link between engineering parameters (i.e., increase the temperature) and physical and chemical effects that can be used to reach a certain goal (i.e., electric or electromagnetic or thermal phenomena). For example, according to this tool, the specific function cracking a nut can be easily translated into a more general function "break a solid" to choose between many different effects listed inside the pointer to Effects DB. Even if this tool is easy to use because design oriented, it lacks of completeness. Not all specific functions have a corresponding pointer to effect and some pointers are still difficult to be exploited because too vague (i.e., "change a dimension", "detect surface properties", "detect volume conditions", etc.).

From 70's, Pointer's idea has evolved in several research works such as Function Oriented Search (FOS) [11]. FOS is a 7 steps procedure based on: the identification of the function we want to improve, the abstraction of this function, the search of those technological areas where the abstracted function is performed for solving similar problems and finally the extraction of best technologies and experts. Results are very dependent on the abstracted function and the search of technological areas.

Pointer to effects has also evolved in commercial products such as Knowledgist [12], and Goldfire Innovator [13] that offers a collection of over 9,000 cross-disciplinary scientific effects. All these existing tools are static because they are based on a prebuilt database that has a fixed set of general functions, a fixed set of effects and fixed links between them. In this article, the authors present a dynamic and semantic database of effects. At difference from existing tools, our database has a physical effects library integrated with a semantic search engine. All existing verb-object pairs can be used as starting function. The links between effects and functions are not prebuilt, but they are extracted by the semantic search engine from documentary sources (such as patents, scientific and technical literature, etc.). Section 2 presents the new dynamic database of effects, section 3 reports on the TT methodology, and an exemplary case study is given in section 4 to show the application of the methodology to the measurement of cornea temperature during eye inspection.

2. Dynamic and Semantic Effects Database

The proposed dynamic effects DB combines together a prebuilt physical effects library and a semantic search engine.

The Physical Effects (PE) library, used to identify alternative technologies, is the core of Kompat. This library has been created collecting and revising scientific effects taken from different pointers to effects and commercial physical, chemical and geometric effects databases. In particular, this library contains a list of effects and technologies classified according to the type of interaction: mechanical, acoustical, thermal, chemical, electrical and electromagnetic. Each effect is associated to a list of words. For example, the concept of "mechanical/compression" is linked to nouns such as "pressure", "compression", verb such as "to press", "to compress", "to push", adjective such as "compressible", technologies (such as "press machine", "pressure roller", etc.) and other technical parameters (such as "compressive coefficient", "maximum tensile stress") and units of measure ("Pa", "bar", "atm", "psi", etc.).

The semantic search engine is used for creating the link between these effects and the function that searcher wants to perform, e.g. crack a nut. In particular, the search engine launches hundreds of queries in order to find patents that describe effects used for performing the input function. Queries are generated for searching the following concept:

Verb + Object + Physical Effect$_i$

Where verb (V) and object (O) describe the function or the problem to be solved, the effect (PE) is contained inside the library. For example:

crack + nut + compression
crack + nut + gravity
crack + nut + explosion
crack + nut + …

Over 10 different semantic algorithms are used to improve patent search increasing precision and recall. In order to increase the precision of results, words having multiple meanings are disambiguated. The semantic search engine proposes the list of all the meanings for both the verb and the object and the searcher has to choose the desired meaning, e.g. for nut we have many meanings such as the hard-shelled seed or the small metal block with internal screw thread. Another functionality for increasing precision is the automatic identification of relevant CPC patent classes for limiting the search to the specific concept (V+O+PE). In order to increase recall, a semantic expansion of the query is used, based on generating synonyms (break, check, …), useful related words (chap, craze, …) and their linguist variants (cracks, cracking, cracked, …) for searching the same concept (V+O+PE).

3. Technology Transfer methodology

As shown in other publications [15-17], this dynamic effects database can be used to perform TT. The TT procedure consists of 2 steps:

- State-of-the-art construction: alternative technologies are identified and divided in technologies existing at the state of the art and new technologies not yet used for the domain under investigation.
- Technology Transfer: new technologies applications are searched in different technological areas.

1. State-of-the-art construction.

Given a specific domain, the goal of this phase is to identify both the technologies existing at the state of the art of a specific context and new technologies not yet used. Thanks to the dynamic effects database, the searcher does not need to know or image the alternative technologies before to search them. Searchers have to translate the function they want to perform in form of verb-object couple, e.g. crack nut.

As result, the dynamic database gives back a map of physical effects and technologies classified according to the interaction field: mechanical, acoustical, thermal, chemical, electrical and electromagnetic, see figure 1. The link between effects and the initial function is represented by the number of patents mentioning the effect itself.

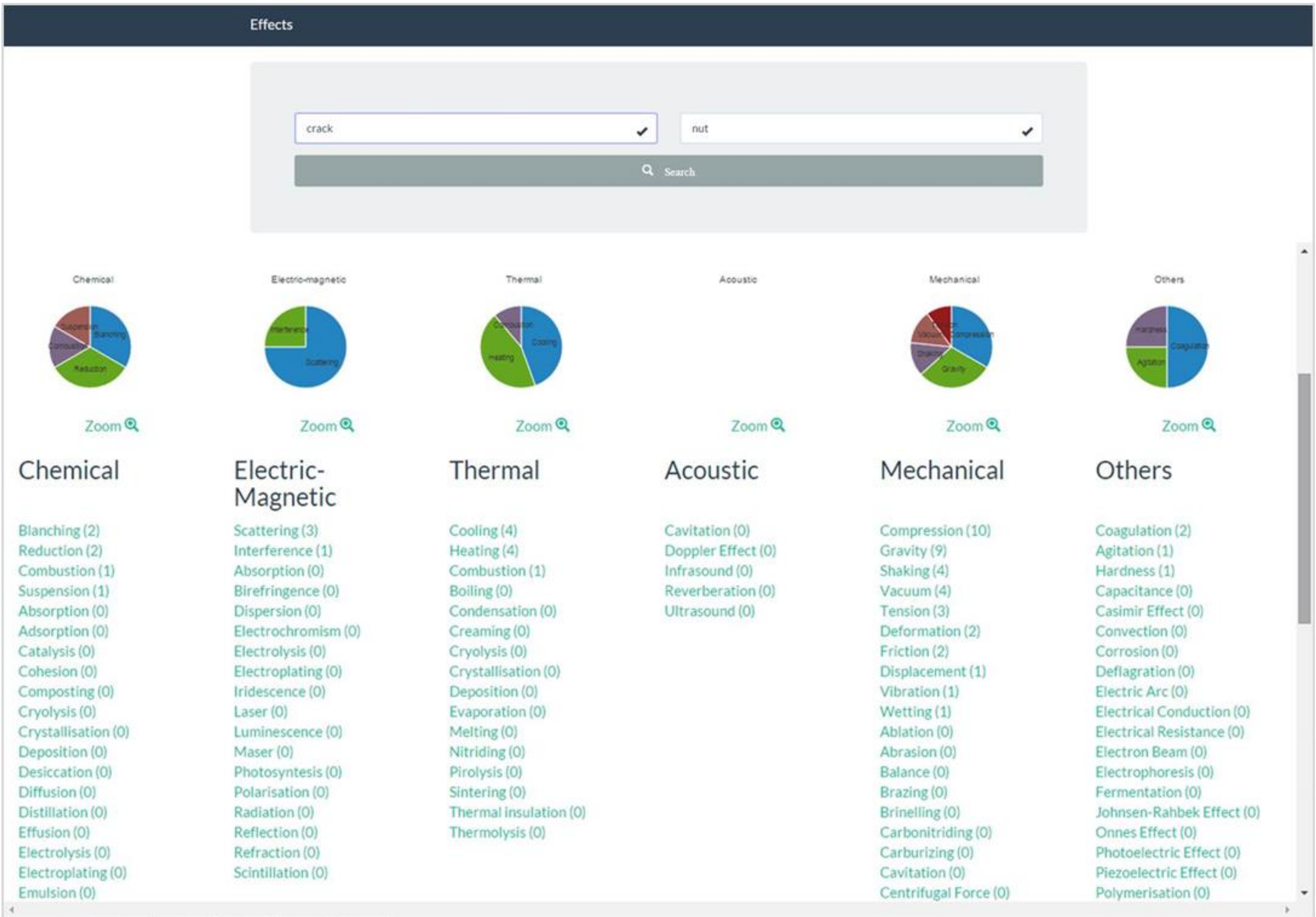

Figure 1 Kompat Effect Database: output for the function "crack nut". Partial list of effects at the state of the art (with patents > 0) and new effects (with patents = 0)

Effects are divided in 2 classes:

- Existing effects: when patents mention an effect for performing the initial function, this effect is considered already existent for the domain under investigation. Each effect is associated with the number of patents, see fig. 1. The number of patents related to each effect is also an index of patent density. Effects with high number of patents are more reliable but this implies also more

competition between players. On the contrary, effects with low number of patents represent pioneering applications but still already implemented by someone.
- New potential effects: when any patent does not mention an effect for performing the initial function, this effect is considered new because it is not yet used for performing the desired function, e.g. crack nut. These effects represent the new patentable opportunities that we call White Space Opportunities (see fig. 1).

For the domain under investigation, patents found represent the link between the function and the effects. Patents found for each effect can be used as the starting point for assessing the technology, acquiring knowledge about a specific technological area, extracting patent trends, monitoring direct and new competitors and more in general supporting decision making activities. For the sake of brevity, these analysis are not presented in this work (this topic is treated in Russo et al. [18]). In the domain under investigation, those effects with zero patents are not linked with the initial function. The next step is based on searching applications of these new effects in different technological areas.

2. Technology Transfer.

The goal of this phase is to search if the White Space Opportunities (WSO) are already used in different technological areas for performing a similar function. In other words, patents belonging to other domain are the link between WSO effects and the function. This search is based on the abstraction of the function (crack + nut) through the generalization of the object (e.g. crack + seed, fruit, shell, plant organ, natural object, …) [15]. Starting from the abstracted function, the semantic search engine launches new queries for searching WSO effects. If at least one patent of another domain describes the use of the WSO effect for performing the abstracted function , this effect is a potential alternative to be transferred in the initial domain

4. Technology Map

During a refractive surgery, before the ablation, the cornea has to be cooled down. During, this process, the temperature of the cornea is continuously recorded by an infrared camera in order to understand when the corneal temperature is below the baseline. The following CPC patent classes have been used to limit the context of the application:
- A61B3: Apparatus for testing the eyes; Instruments for examining the eyes.
- A61B5/6821: Arrangements of detecting, measuring or recording means, e.g. sensors, in relation to patient's eye.
- A61B8/10: Diagnosis using ultrasonic, sonic or infrasonic waves for eye inspection.

1. State of the art construction

The function we want to perform is "measure the temperature" of the cornea.
- For the verb "measure" among all the meanings we choose "determine the measurements of something or somebody, take measurements of". This verb is semantically expanded by the patent search engine with other verbs such as: detect, monitor, determine, sense, measure, etc.
- For the object "temperature" we choose the meaning "the degree of hotness or coldness of a body or environment (corresponding to its molecular activity)" that is expanded with terms such as: heat, boiling point, curie point, physical property, etc.

After the selection of desired meanings, the patent search engine launches an automatic search strategy for each effect contained inside the PE library. For example, for the physical effect of Ultrasound, we will search for:

ultraso or ultra so* or ultra-so* or *sonography or echography or ((#### khz or #### mhz ##### hz) and (sound*))*

Where:

* Truncation replacing any number of characters

Truncation replaces exactly one character

The output of the dynamic effects database is the list of PE for "measuring the temperature of the cornea" divided in: existing effects (e.g. infrared) with number of patents > 0 and WSO effects (e.g. Doppler effect) with number of patents = 0. 8 existing effects have been identified by the database. All the remaining effects of the database (over 200 effects) are WSO effect because no patents describe them. By a manual check of the found patents, 7 out of 8 physical effects are really used for measuring the cornea temperature, while the cryogenic effect is a false positive because the patent found describes the cryogenics as an effect for cooling down a cornea sample.

2. Technology Transfer

Among all WSO effects, 19 of them have related patents describing the use of these effects for measuring the temperature of objects in general. These patents belong to different domains. For this task, the search engine investigates patents outside the CPC classes related to the eye inspection searching inside the class G01 (related to measuring and testing) or the entire patent database. In figure 2, the 19 new potential effects for measuring temperature are highlighted in green. These are potential effects suitable for TT because already used for measuring the temperature but not for the eye inspection.

5. Conclusions

A dynamic pointer to effect database integrates a brand new PEs library with a semantic search engine. This database is a function-oriented tool that automatically suggests which effect can be used for performing a certain function searching for an application inside technical and scientific literature, such as patents. If patents found belong to the domain under investigation, the physical effect described is a known solution at the state of the art. Instead, if patents belong only to other domains, the physical effect can be used for Technology Transfer activity. The number of patents found is an index of the feasibility and maturity of the application. All physical effects suggested are also organized according to the

7 TRIZ fields: mechanical, acoustic, thermal, chemical, magnetic, electric and electromagnetic.

In addition, having the list of patents for each effect can be very useful for extracting further information. From the analysis of these patents we can understand which technologies are the most used and which ones are pioneering, who are the main players and which are the technological patent trends of a specific domain. Also for new transferable technologies additional information can be extracted from patents, such as who are the main experts, which are the most advanced domains, which are the potentialities and drawbacks.

The semantic search algorithms and the PE library are still under development in order to increase precision and recall of both technologies identified and related patents. The list of effects and related patents is the current automatic output of the dynamic effects database. This result can be represented in a Technology Map that consists of a concise overview of a technological areas. This map together with additional information extracted by patents allows managers and experts to have a comprehensive and fast overview on the situation, increasing awareness and consistency of decision making.

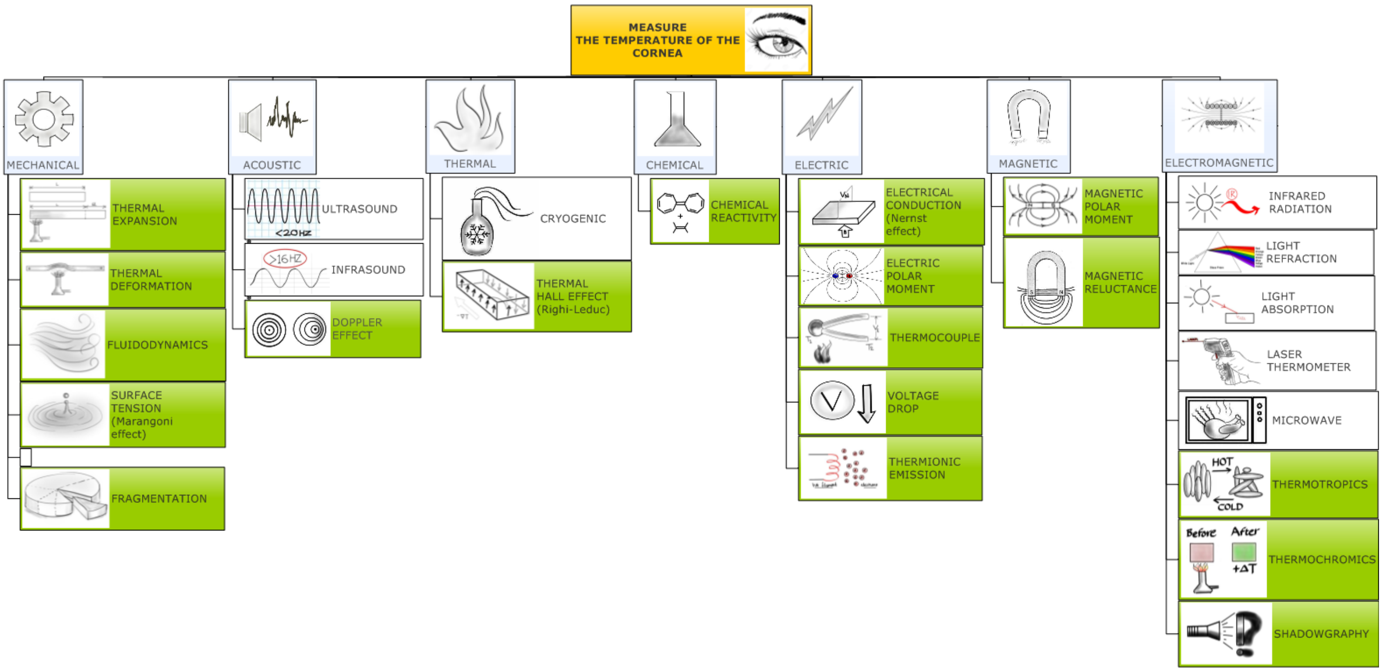

Figure 2 Technology Map shows the effects existing at the state of the art and new potential effects suitable for technology transfer (in green). These results are a graphical representation of Kompat output obtained for the function "measure temperature".

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