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**“Should we manage the process of inventing? Designing for patentability.”
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Abstract: The IP design is often neglected by the management literature, whereas the issue of the strategic IP management begins with IP creation. This paper intends to deal with IP as an asset to be designed and focuses on IP design by ensuring novelty and inventive step of the inventions and not their quantity. By building on the most recent design theories like Concept Knowledge design theory, this research introduces a general framework of patent design that allows controlling for “patentability” criteria, describe a patent in a unique way using actions, effects and associated knowledge and consider reasoning of person skilled in the art. Using the introduced model, the existing patent design methods are compared and their performance characterized using an introduced patent design model. The results show that patent proposal quality depends on the capacity to extend the existing knowledge combinations; to overcome the initial design reasoning of person skilled in the art and ensure sufficient inventive step and novelty. Finally, the patent design model actually demonstrates that there is an unexplored property of design theories - non-substitution - showing that the order in design is irreversible and influences the quality of results.

Key words: intellectual property, innovation, patent design, C-K Theory, patentability criteria, person skilled in the art

Intellectual property: from an existing asset to an asset to be designed

INTRODUCTION

The proposed paper deals with the issues of the intellectual property (IP) design. The IP is often seen as a source of competitive advantage, as a strategic element that can ensure revenue flows or just demonstrate the organizational entity's innovative capacity. Though, the IP management is becoming ever more complex and resource demanding. The reasons are multiple. First, there is multiplicity of patents filed: according to the [NYtimes](#), « *the number of patent applications, filed each year at the United States patent office has increased by more than 50 percent over the last decade*» (NYTimes, 2012). Second, the legal risks involved are making it even more challenging. The number of patent litigation increases drastically over time according to the Stanford University analysis, as much as \$20 billion was spent on patent litigation and purchases in the smartphone industry in 2010 - 2012. Third, the number of actors operating in the world of industrial property increased nowadays. In addition to the protection by patentees of their inventions, there is a whole second-market of non-practicing entities that provide new opportunities for buying and selling patents (Chien, 2010). The ecosystem is more complex and hard to manage than ever before featuring the variety of business models and actors like patent lawyers, designers of IP, licensing institutions, IPO, patent consultants, patent brokers, patent pools, standard setting associations etc., despite the increasing help and contributions of Information and Communication Technologies. Moreover, new actors are still emerging such as defensive patent aggregators and superaggregators (Hagiou et al., 2013). From the one side, IP legal frameworks tend to be complex. From the other side, economic logic behind is resource demanding for the companies. IP portfolios are too costly and the ways to create profitable IP portfolios are not evident. This overwhelming complexity causes speculative bubbles, leading for the creation of actors that tend to decrease the system complexity or simply profit from it (taking the case of patent trolls). How should we deal with IP without losing its strategic potential and do not being lost in its complexity?

This research intends to deal with the IP as an asset to be designed. The existing literature is mostly focused on the the existing intellectual assets (Teece and Pisano, 1994, Teece et al., 1997), on the capacity to appropriate them and ensure their competitive

advantage. Yet companies could proactively generate their intellectual assets to protect and strengthen the business opportunities by focusing on the *ex ante* phases (Lindsay and Hopkins, 2010). There exist methods that take into account IP design: TRIZ, design analogy, genetic algorithms (Altshuller, 1999b, Felk et al., 2011, Jeong and Kim, 2014, Koza et al., 2004). Though, their performance is not evident, the expected results in terms of IP are hard to quantify and the comparison is not obvious. To the best of our knowledge, there is no theoretical framework that defines what means patent design. The methods define certain properties for patent design but it is impossible to evaluate them since a general model of patent design is missing. This research tackles the following questions: **what is the general framework of patent design and how to characterize the performance of the patent design methods?**

To address these research questions we will rely on the recent advances in design theory. Design theory is chosen since they allow for knowledge expandability, for generic process of expansion which includes the capacity revise objects identity and work on different knowledge structures (Dorst, 2006, Le Masson et al., 2013). Moreover, design theories address issues that go beyond the scope of classical models and open possibilities to invent new methods, new organizations, ... (Le Masson et al., 2013). Recent advances in design theory have led to propose formal models of design that are independent of the language of objects (Hatchuel et al., 2011). As a consequence, the generic character of these models enables to consider a patent or a patent portfolio as a possible design objective. Overall, IP design is not as strange as it might sound: on the one hand, peer-reviewed journals in the discipline of the engineering design (e.g., Journal of Engineering Design or Research in Engineering design) already tackle the issue of the conceptualization of patent information or its interpretation as a design object and shows that there is a link between the IP and engineering design (Koh, 2013, Koza et al., 2004).

By building on the most recent design theories like Concept-Knowledge design theory (Hatchuel and Weil, 2009), this work introduces a general framework of patent design that allows controlling for “patentability” criteria, model a patent in a unique way using (action effect, knowledge) model and consider reasoning of person skilled in the art. Using the introduced model, patent design methods (TRIZ, design by analogy, genetic algorithms and CK Invent) are compared and their performance is characterized. The results indicate that patent proposal quality depends on the capability to extend the knowledge basis that is

not limited to the original knowledge combinations but requires expanding the initial design reasoning of person skilled in the art and ensuring sufficient inventive step and novelty. Moreover, the patent design revealed an unexplored property of design theories - non-substitution, showing that the order of partitioning in design matters and it influences the quality of results.

The paper is organized as follows. First, we present the legal definition of patent and the existing methods of patent design. Second, we build on the design theory advances to see how the design logic takes into account patent design logic and introduce a general framework for patent design. Third, we build on this framework to compare the patent design methods and quantify their performance. We conclude with a discussion and draw directions for further research.

2 LITERATURE REVIEW

2.1 Intellectual property: On the definition of patent

According to the World Intellectual Property Organization (WIPO), Intellectual Property (IP) refers to «creation of the mind such as inventions, literature and artistes works, designs and symbols, names and images in commerce». It is protected by law through patents, copyright and trademarks. Our focus in this article is on patents which represent a document, issued, upon application, by a government office (such as the European Patent Office (EPO) or United States Patent and Trademark office), which describes an invention and creates a legal situation in which the patented invention can normally only be exploited with the authorization of the owner of the patent. Patents offer a legal right title for the owner to prevent others from using, making or selling the protected invention in a country where patent has been granted for an allowed period of time.

“Invention” is defined as a solution to a specific (mostly technical) problem. An invention may relate to a product or a process. Not every idea can be patentable: only the ones that incorporate nonobvious steps. To be protected by a patent, invention has to meet several criteria: 1) the invention must consist of patentable subject matter; 2) the invention must be industrially applicable (useful); 3) it must be novel; 4) it must exhibit a sufficient “inventive step” (be non-obvious for a person skilled in the art); and 5) the disclosure of the invention in the patent application must meet certain standards.

2.2 On the logic of Patent design

Which methods or practices account for “patent design practices”? We have identified several ways of designing patents. We structure them in five different methods: 1) Technology-first; 2) TRIZ; 3) Genetic programming; 4) Design analogy methods; 5) CK Invent (See Table 1).

2.2.1 Technology-first

Patents are filed once a technology is first developed (Ernst, 2003, Van Zeebroeck and Van Pottelsberghe de la Potterie, 2011) or proof of concept is obtained. We call this a Technology-first method since it assumes that technology is first developed or prototypes are designed in order to fill patent application. The technology-first approach consists in pursuing first of all the exploration of a reference technology (Table 1). The goal is to mobilize the existing knowledge to find new invention proposals. This is a reference model for patent design where patents are issued for the technological inventions. In this case the technology need to be well described, its novel character ensured. Claims are often seen as a strategic section of the patent document that influences patent quality. Claims editing in accordance with prior art can be seen as a design activity which is made by a patent engineer. In this case, the collaboration with an IP office with higher level of expertise is crucial. It might determine the patent’s future quality and condition a probability of be granted a patent.

As pointed by Cavallucci et al. (2009), the need to rebuild design practices in enterprises is strongly felt both in terms of human skills and methodological expertise. In case we deal with the assets *ex ante*, patents appear as an objective that a group of designers and scientists have to achieve before the technology is commercialized or its exploration started. The latter brings companies, research centers to actually seek for methods that allow maximizing the number of potential patents, pursuing creativity in patent design, possibility of strategic inventing (Nissing, 2005).

2.2.2 Inventive problem solving - TRIZ

Nowadays patent design is often associated with inventive problem solving – TRIZ (Russian acronym that stands for "a problem-solving, analysis and forecasting tool derived from the study of patterns of invention in the global patent literature"). TRIZ is a widely

accepted method of inventive concept generation that emphasizes predictive methods and evolutionary trends based on the description of contradictions and potential solutions (Table 1). TRIZ resulted in creation of TRIZ-based methods such as contradiction theory, substance-field analysis, and technology evolution patterns (Altshuller, 1999a, Altshuller, 1999b, Altshuller and Williams, 1984). For instance, tools to automatically identify contradictions in technical systems based on patents textual analysis (Cascini and Russo, 2006), axiomatic conceptual design model that combines TRIZ and the functional basis work were proposed (Zhang et al., 2007). In addition, TRIZ was combined with strategic inventing to place more emphasis on differentiation and patent protection (Nissing, 2007). TRIZ offers the existing model for patent design associated to the logic of abstraction and analogy. The ideality in TRIZ determines proximity of how close the new solution is to the ideal system so it presumes that the ideal system is determined. The ideality aims to increase product benefits and reduce costs. Contradiction solving seeks to identify and eliminate contradictions by deploying 40 principles contradiction matrix which allows solving about 1500 technical contradictions based problems. Liang et al. (2008) propose method of mining patents based on contradictions. By indicating that the contradictions and corresponding inventive principles are too abstract and general, the authors claim to help innovators by using text mining to relate directly examples of published patents in patent design activity using TRIZ related methodology. Authors explore how to ensure patent search and use text mining and semantic analyses methods to automatically analyze the existing IP databases and relate them to the new innovative challenges, to verify the risks of patent infringements (Cascini and Russo, 2007, Liang et al., 2008, Bergmann et al., 2008). TRIZ is also to deal with local innovations of an existing patent – design around. Design around is built based on patent infringement judgments to ensure that new techniques are substantially different from the existing patents. Hung and Hsu (2007) demonstrated that design-around strategies, function model and value analysis in TRIZ can determine the design problems to be solved and TRIZ can be applied to solve them by increasing innovativeness and avoiding incremental trial and error solutions. Yet, by admitting its patentability, one can argue how innovative will be a solution obtained through design-around method. Overall, TRIZ together with problem analysis and semantic tools are powerful instruments for patent strategy development. Though, TRIZ is often criticized for its limited inventive novelty due to the departure from the already

issued patents – existing physical system. Reich et al., (2010) demonstrated that TRIZ based methods are suitable for ‘in- and near- box’ designs.

2.2.3 Genetic programming

Genetic algorithms were applied for patent design (Koza et al., 2004). This method consists in dealing with the automation of nonobvious, knowledge intensive processes: the evolutionary and the invention processes by determining the exploration spaces and ensuring the search using the genetic algorithms. Genetic programming transforms an initial population into a new generation by iteratively applying the operators of crossover, mutation, gene duplication, and deletion (Goldberg, 2006). A new solution can be generated close to the prefixed exploration space and is always built on the existing knowledge (Table 1). The new solutions can ensure the inventive capacity and lead to propose counterintuitive solution. For instance, the authors replicated an invention of negative feedback by AT&T through an automated design and invention technique patterned after the evolutionary process in nature, genetic programming. They show that the genetic algorithm can synthesize analog circuits and duplicate their functionality. In addition they demonstrate how this technique can produce many additional inventions inherent on the evolutionary process. Independently from patents, the evolutionary computation approach was used for concept generation to increase quality and diversity of design concepts by combining the evolutionary approach with TRIZ.

2.2.4 Design by analogy

Design by analogy methods applied to patent texts (Fu et al., 2015, Jeong and Kim, 2014, Murphy et al., 2014) attempted to be used for patents creation by assuming that similar problems can appear in technologies that have similar functions and properties (Table 1). Design-by-analogy extracts functional analogies from patent databases and allows designers to find analogies with the existing patents (Fu et al., 2015). As the authors underline, this method quantifies the functional similarity between the design problem and patent description and this, lead to generate new concepts using design-by-analogy. It is based on functional vector space model analogy search engine (Murphy et al., 2014) which applied to patent databases create a vector representation of latter based on functions. For instance, Jeong & Kim (2014) aim to generate patents by creating an analogy between mature wireless router and emerging wireless charger. The authors argue that engineers or

designers can use this method systematically to create patents. First, problem solving concept resolved by each patent has to be identified. The new technology by building on one similar property or function of the old technology seeks to incorporate by the analogy other different properties or functions of the old technology by enabling new discoveries. As the study indicates, from 352 patents on wireless router technology, 227 patents on wireless charger technology were used. Murphy et al. (2014) claim that a robust design-by-analogy methodology would enable designers to identify nonobvious analogous solutions. Yet it is limited once applied to novel properties or functions in case of disruptive technology where the analogy cannot be pursued.

2.2.5 CK Invent

The more recent design formalism like Concept-Knowledge (C-K) design theory was used to account for patent design. Felk et al. (2011) mobilized C-K design theory to propose a patent proposal generation method when problem is not necessarily given in advance. The authors consider a patent as a design purpose. Following operators introduced by C-K design theory (Hatchuel and Weil, 2003, Hatchuel and Weil, 2009). This method aims to strategically position future inventions in a predefined patentable design space. The problems are not defined a priori (Felk et al., 2011). It is shown that an invention proposal can be obtained by adding to an existing entity a property that do not exist in knowledge basis. This is called an expansive partition in C-K Theory (see section 3 for more details). This method derived from C-K design theory is called CK Invent. The authors exhibit how by incorporating design logic one can increase the quality of future inventions and increase the number of patents proposals. But how to control the quality of partitions? How to quantify the performance of CK Invent?

Table 1 Patent design models

Method	Problem space	Model of patent generation
Standard: Technology-first	Problem is based on a technology developed/ in advance	Identify patentable features in technology and fill a patent proposal
TRIZ (Altshuller, 1999b)	Problem defined in advance	Patent design around based on contradiction solving principles

Genetic programming to automatically synthesize complete designs (Koza et al., 2005)	Is not given <i>a priori</i> but the exploration space is defined as well as selection criteria (fitness function)	Based on functionality of existing patents (Optical lenses systems)
Design analogy method (Jeong and Kim, 2014)	Is not given <i>a priori</i> but the space for exploring analogous technology is defined	Creation by analogy assuming that similar problems appear in technologies with similar functions, properties. Deducing functions from a pre-defined patent set. (Wireless router/charger)
CK Invent (Felk et al., 2011)	Is not given <i>a priori</i>	Based on C-K design theory operators

The literature shows that there exist methods for patent design but these methods are difficult to compare, their performance needs to be quantified. As we observed, all these methods make a reference to the existing knowledge sets (patents, publications, know-hows...). They help to structure the knowledge available to design patents and to fabricate the inventions in the original design fields. Though, the general theoretical framework on how to account for patent design is absent. Our research question: **What is the general framework of patent design and how to characterize the performance of the patent design methods?**

3. THEORETICAL FRAMEWORK FOR PATENT DESIGN

3.1. Requirements to define a theoretical model for patent design and relevance of design theory

Theoretical model for patent design has to clarify the language of patent and its expected performance – a possibility to control for patentability criteria and has to be invariant to the types of knowledge structures. Why are contemporary design theories capable of doing this? Is Design theory suitable to define a model for patent proposal design?

Design can be seen as the simultaneous generation of objects and knowledge. The one way is to think of generation as a *combination* of existing objects or elements, likewise

language generates new texts by combining invariant signs or letters. Though, Hatchuel et al. (2011) showed that limits of this combinatorial principles and demonstrate that design theories go beyond pure combinatorial strategies and take into account dynamic transformations, adaptations, hybridizations, discovery, invention and renewal of objects discovery. The authors demonstrate that the design theories seeks to increase both their generativity, *i.e.* their ability to produce design proposals that are different from existing solutions and design standards and ensure their robustness, *i.e.* their ability to produce designs that resist variations of context. Therefore, generativity and robustness of design theory will ensure the sufficient character of inventive step, the inventions' applicability. Patent design process can be seen as a design activity where one can control for inventive and novel character of patent design process. **How the design theory clarifies the design of patents, take into account the patentability criteria?**

This research builds on the C-K design theory since it is independent from a particular knowledge domain (Hatchuel and Weil, 2009). Concept-Knowledge (C-K) design theory (Hatchuel and Weil, 2003, Hatchuel and Weil, 2009) defines the design process as a continuous refinement of a concept described by various properties that need to be met based on the existing knowledge and producing new one. The process of design is defined as a double expansion of the concept and knowledge spaces through the application of four types of operators. Design theory is useful for patent modeling since it separates a knowledge model and design reasoning how to use the existing knowledge to structure the unknown.

3.2 Patent model and Patentability criteria

3.2.1 Modeling patent as an (Action, Effect, Knowledge)

A patent can be represented as a solution to a technical problem that differs from the prior art. The solution that comprises the object description and the interventions performed by an agent (human, fluid...) on an object can be characterized as actions. The technical problem to be solved can be defined as a set of effects. Knowledge defines the prior art and the results obtained during the invention preparation. The knowledge basis comprises 1) public knowledge: patents, research, commercial papers, all the available documentation and all the knowledge generally available and evident for the person skilled in the art; 2) knowledge developed by an inventor during his research or design process. In this regard

patent can be seen as combination of actions, effects and knowledge (Couble and Devillers, 2006). Patent is a proposition where *Action* represents the intervention made on objects and their interrelations. *Effects* are actions' consequences and *Knowledge* is the set of technical information used by the invention.

Using the famous Nespresso capsules patented by Nestec – an R&D of Nestle example (US20100239717 / EP 2364930 A2), let's analyze Claim 1:

“Capsule for the production of a beverage, more particularly coffee, in a beverage production machine comprising 1) a capsule holder with relief and recessed elements; said capsule comprising: 2) an inverted cup-shaped body forming a chamber containing beverage ingredients, preferably ground coffee, a bottom injection wall, a sidewall; a delivery wall which is sealed to the body; 3) optionally, a filtering wall placed between said chamber and the delivery wall characterized in that the delivery wall comprises a calibrated orifice or comprises perforating means to provide a calibrated orifice and in that the beverage delivery wall is not tearable against the capsule holder during extraction but provides through the restriction created by the calibrated orifice a certain back pressure which generates an elevated pressure in the capsule during extraction»

In this text *“for the production of a beverage, more particularly coffee”* is an effect that the new invention offers. The knowledge is embedded in the principles of elevated pressure in the capsules and action is the process 1-3 described using knowledge elements to achieve the desired effects. (A, E, K) model defines the patent proposal. Each patent is a combination of new actions and or effects with the associated knowledge that explains how certain effect was obtained by one or several actions. In this research, (A, E, K) model is used to characterize patent as a design objective. Definitely other ways such as Functions – Behavior – Structure (Gero and Kannengiesser, 2004) or contradiction – effects principles (Glaser and Miecznik, 2009) might be used to define patent.

3.2.2 Patentability criteria

Patentability criteria and definition of person skilled in the art

In order to be issued, a patent has to be a subject of patentability criteria: patentable subject matter, ensure usefulness of the invention, novelty, inventive step and enable disclosure of the invention (Table 2). Patentable subject matter is open to all fields of technology. The

non-patentability is often due to specific methods of treatment for living organism schemes and models that perform purely mental activities; methods that exist in nature (for further details see Article 27.1 of the TRIPS agreement). The patentability of the invention can be questioned using morality principles as well.

Usefulness of the invention, its applicability defines the practical purpose of the proposed invention, the possibility to actually manufacture the proposed product and implement a part of the process to serve its purpose. It is the utility of the proposed invention.

Novelty and “inventive step” are appreciated with respect to the state of the art at the date of patent application. Novelty is a critical criterion and the invention appears to be novel when it is not anticipated by the prior art. *“State of the art shall be held to comprise everything made available to the public by means of a written or oral description, by use, or in any other way, before the date of filing of the European patent application”* according to Article 54(2) EPC.

The inventive step of a proposition questions the nature of the invention on its obviousness for a person having ordinary skill in the art. The question “is there inventive step?” only arises if there is novelty. WIPO suggests analyzing inventive step in relation to the problem to be solved, the solution to that problem and the advantageous that the invention offers to the state of the art. Generally, if a person skilled in the art (PSA) is capable to pose that problem, solve it similarly to a proposed invention and predict the results – the inventive step is missing. The definition of PSA differs according to the national patent codes. For instance, in Europe patent proposal follows problem – solution scheme that starts with the “closest” state of the art where we seek to identify the distinctive characteristics of the proposed inventions and seek for the technical effects of these differences, the connections between them. Finally, the appreciation of the evidence needs to be indicated: how the invention should be used by the PSA, how it can be reproduced. In France, PSA is considered to be an expert of one technical domain or maybe the closest ones. Secondary considerations that are objective evidence of non-obviousness are not really examined which often results in trivial inventions. On the contrary in the US and Japan based systems, secondary considerations must be evaluated. In Japan and the US, the inventive activity is not based on problem – solution but on a production of unexpected, advantageous results, unexpected technical effects. In Japan, PSA has common general knowledge relevant to the art of invention, PSA is able to use ordinary

technical means for R&D, to exercise ordinary creativity in selecting materials and changing designs, is able to comprehend as his knowledge all technical matters in the field of invention and in the fields of technology and may be thought as a group of persons (JPO examination guidelines). These differences in practices of examination influence novelty and inventive step of patents across different countries. The patent examination depends on the definition of PSA. The better the role of PSA is qualified and taken into account in concept definition and patentability criteria, the better the patent examiner knows how to treat each patent proposal and thus, can accelerate the evaluation and the editing procedure.

The last criterion is a disclosure of the invention that defines whether the proposed invention is sufficiently well described in the application that the PSA can carry out the invention claimed. These are the criteria that inventor has to fulfill to be granted patent rights.

The patent examiner should ensure that patentability criteria are met. His examination depends on the knowledge available and the reasoning that the inventor followed to invent a new solution.

3.3. Patent design model from the design theory perspective

We can now introduce a model of patent design in C-K theory. As shown in Section 2.1 the patentability criteria are defined based on the person skilled in the art (PSA) who disposes certain knowledge basis and the reasoning that the inventor follows to create a patent proposal. Knowledge space includes public knowledge (K_0), which comprises patents, publications, customer references, internal company expertise – “state of the art”. PSA presumed to be a skilled practitioner in the relevant field, who is possessed of average knowledge (in A, E form) and ability and have had at his disposal the normal means and capacity for routine work and experimentation. K_0 should be evident for PSA. Knowledge is then structures as sets of actions, effects and knowledge on their existing and possible relations: $K_0 = A, E + K$ (i.e., $R(A, E)$) – see Figure 1.

According to the C-K formalism concept is “undecidable” in knowledge basis meaning that its logical status is neither true nor false (Figure 1). The concept is defined as a combination of actions and effects that lack a logical status yet (at least for PSA). The concept is defined as a combination of actions and effects meaning that a concept in C-K is

defined as (A-E). The patent can be achieved through (A-E) concepts exploration and can be defined as new (A, E, K) (Couble and Devillers, 2006) that fulfills patentability criteria. The knowledge space has to take form of actions, effects and their relations. **Patent design appears as designing a new (A, E, K) proposition that is not already in K_0 and PSA (K_0) does not consider the patent proposal as obvious.**

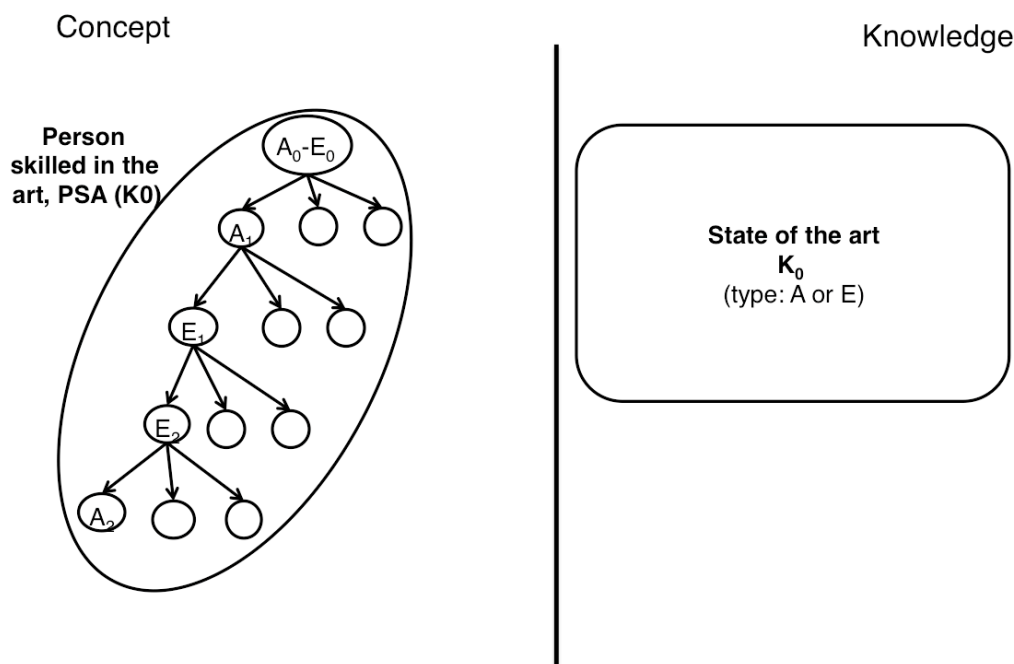


Figure 1. C-K for patent design logic

If the dominant technological proposition already exists, the reference solution in the form (A_i, E_i, K_i) can be determined and the patent exploration is often consisted on extracting potentially subsets (A, E, K) from the properties of that technology and checking its patentability (Figure 2). So a patent is a new sentence made of A, E which meets patentability criteria (Table 2): 1) Not all E_i, A_i or their combinations can be patentable (patentable subject matter); 2) Invention is considered to be novel only when Action (interventions made on objects) and Effects (consequences brought by actions) don't make part of a common knowledge and as a result new δK is created $(A, E) \notin K_0$. 3) Inventive step is defined as if one is able to incorporate all the learning that PSA can make in the domain, $\exists K_0 : PSA(K_0)$. If there is an expansive partition A- or E-type where $(A, E) \notin PSA(K_0)$, it can be stated that the inventive step is ensured. Novel actions and/or effects based on the existing state of the art are proposed. It is important to underline that

not all the concepts in C-space will result in patent proposals. In case of restrictive partitions, they are included in $\exists K_0 : PSA(K_0)$; 4) Minimal description need to be ensured in order to disclose the invention $(A, E) \subset (K_0 \cup \delta K)$. In this case $(A, E) \subset (K_0 \cup \delta K)$ is a new designed knowledge.

Table 2: Patentability criteria

Patentability Criteria	Interpretation in patent model (related to PSA)
Patentable subject matter	Ei and Ai under investigation are not subject of non-patentability (see Article 27.1 of the TRIPS Agreement)
Usefulness of the invention	Ei useful and Ai feasible
Novelty	$(A, E) \notin K_0$
Inventive step	$(A, E) \notin PSA(K_0)$
Disclosure of the invention	$(A, E) \subset (K_0 \cup \delta K)$

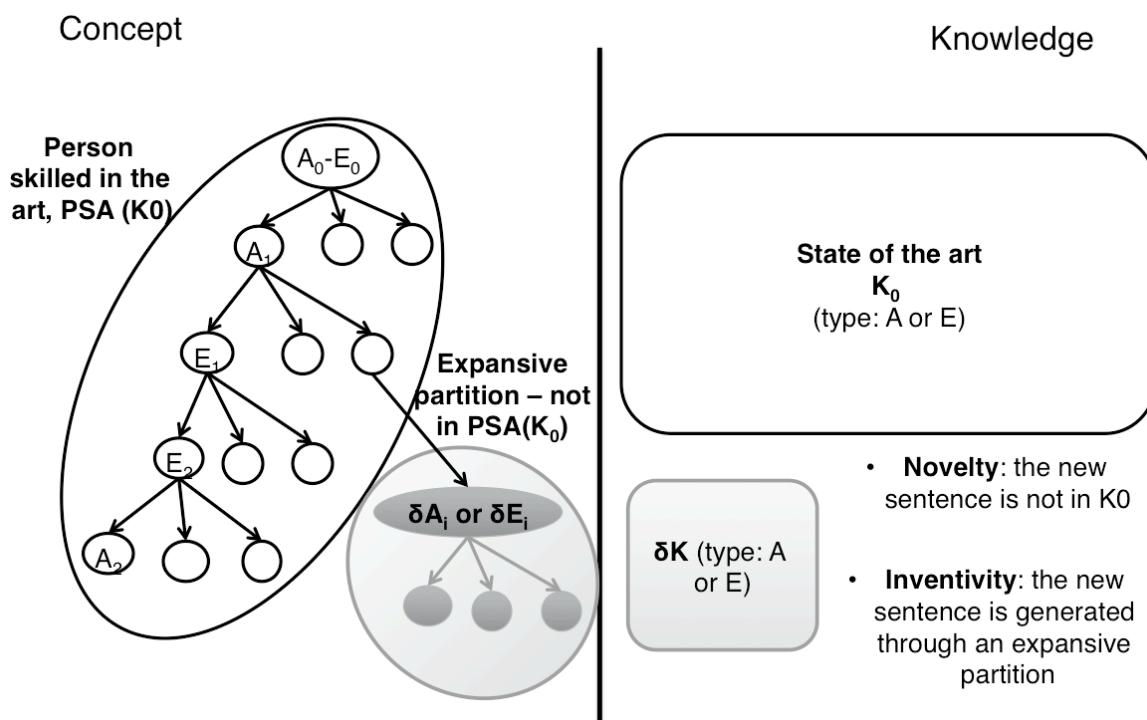


Figure 2: C-K Models based on A, K, E and inventive step

Patent proposals require expansions in both C and K spaces that are based on new Actions or new Effects. These expansions ensure inventive step of new patent proposals, increase

the inventive power of inventions. Different types of expansions influence the way $PSA(K_0)$ will evaluate the proposal and provide a possibility to control for patent quality.

We identify **three types of expansion to control an invention quality** (see Figure 3):

- Keeping Action and Effects but create new relations between them/ new dependencies
- Creating new effect for the existing action
- Creating new action for the existing effect

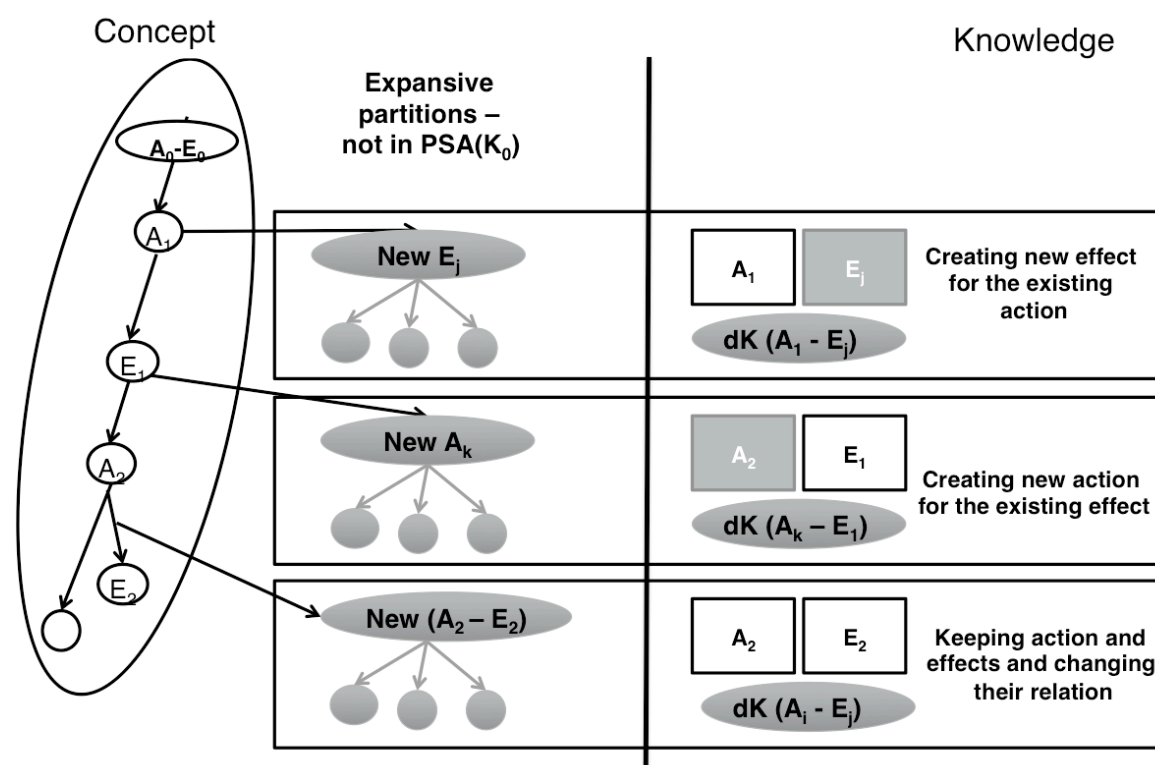


Figure 3: Strategies to control for (A, E) expansions

In the first type, the exploration starts by listing the known action and effects, their relations. The purpose is to build on the identified, previously independent $(A_2 - E_2)$ sets and create independencies between them or change their relations. In this case $\delta K(A, E)$ that redefines the $(A_2 - E_2)$ relations is created. New actions or effects do not appear but their relation is redefined. This process - *Patent first by keeping (A-E) but changing their relations-* is similar to the patent design around (Figure 3).

While pursuing breakthrough innovation, actions, effects and associated knowledge are often missing. According to the C-K theory, creative design requires an expansive partition, which expands the concept space. These expansive partitions significantly

modify or propose new actions and effects that generate new “sentences” – new ideas for patent proposals (Figure 3). They add new knowledge to the K space that can have A or E types of partitions and are not evident for PSA. These expansive partitions obtained by *Creating new actions or new effects* should be examined to fulfill the criteria of novelty and inventive step. Novelty implies the absence of A-E relations in the knowledge basis; inventive step means that A-E is not evident for PSA (Table 2). Moreover, disclosure of the invention is achieved once the (A, E, K) can be understandable and repeatable by technical experts.

Patent design process

Patent design process is exhibited in Figure 4. The exploration starts by organizing knowledge structure in order to define high-level (A-E) concepts that enclose a wide range of opportunities using C-K design tools (see figure 2). A conjunction is achieved once a new concept is true in K and a combination of (A, E) lead to create new knowledge resulting in patent proposal.

Patent design means designing a new (A, E, K) sentence that corresponds to Table 2. Patent design starts by identifying new innovative field on which the design process will focus (Figure 4). Once a generic concept is established, a mapping of the high-level effects and actions should take place. These high level actions or effects can correspond to some patent classification and represent design concept (A₀- E₀). Normally, some new words (new types of actions or effects) can be introduced here to enabling the exploration of new design space (see 3.4 for an illustration). To map the corresponding actions and effects, knowledge bases based on A, E, K are built using patent databases, scientific articles, etc. This initial mapping allows identifying enabling patents, relations between different inventions (for instance, by integrating patent citations analysis) but also incorporating issues discussed in research papers, competitor analysis, industry trends. The goal is to identify potential knowledge gaps. Mapping of the initial knowledge basis (K₀) represents a set of initial issues. We do not claim here to analyze all the patents related to the domain but we seek for a general understanding of the field problematic “Claims” part of a patent is used. Normally 10 - 20 % of patents are used to build K₀. This phase is mostly conducted in K-space but a tree structure of C-space helps to put together patent propositions as concepts in the C-space where each patent is presented as a relation between A and E, and partitions are actions or effects. We want to underline that this phase

is required when the research area is mature and company aims to identify the new possibilities and new offers that are still "free of IP" – possible breakthroughs that are easier to attain. In addition, it might be helpful to determine person skilled in the art – a general knowledge that is considered obvious in the research area – should be characterized. Usually definition of $PSA(K_0)$ depends on the IP legislation where designers wish to fill patent application.

Next, workshops are organized for ideas production and knowledge simulation following formal model of creative thinking – C-K design theory. These workshops aim to extend the initial $PSA(K_0)$, based on new actions, effects or by creating new connections between the existing A and E. Once new sentences are generated, they are verified on patentability criteria and knowledge exploration is organized. As a result, K basis is expanded and to ensure conjunction in C-space knowledge production is required to proof the concepts, build new partnerships or just fill patent applications.

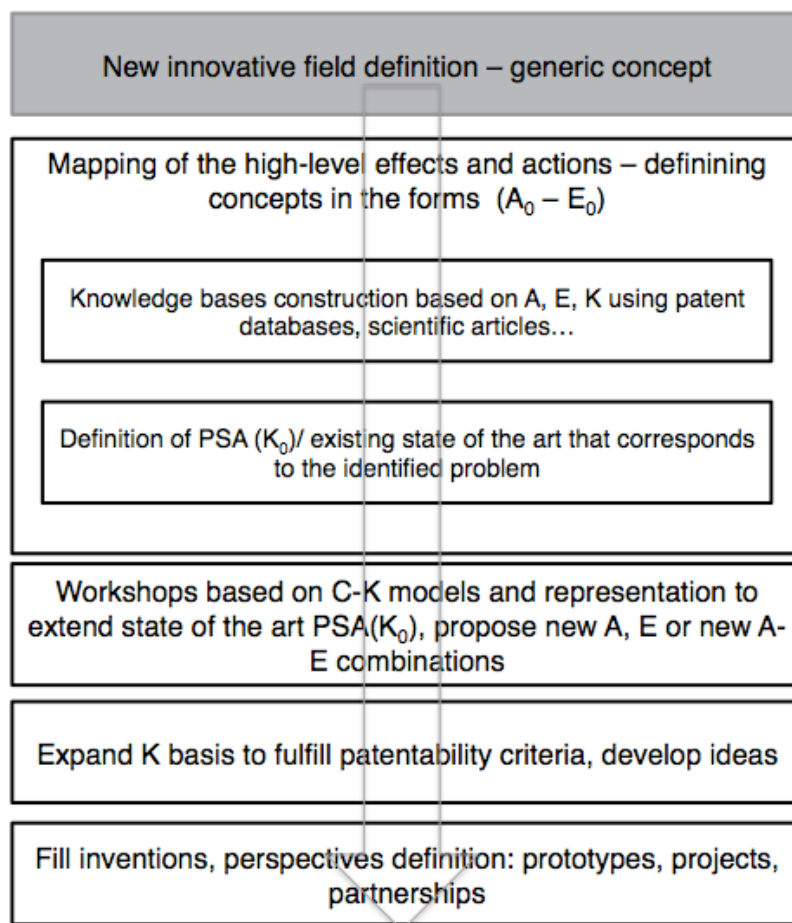


Figure 4: Patent design process

3.4. Patent design in practice – Illustration at STMicroelectronics

The experiments initiated by Felk et al. (2011) in 2010 and continued by the authors of this paper (in 2012 – 2013) was conducted to test patent design model and study how by using patent design model and patent description in (A, E, K) model, teams in different technological areas were able to deploy patent proposals design methods.

Experiments were conducted at STMicroelectronics (ST). At ST, one of the leading European Semiconductor companies, the process of patent design was initially tested in 2008. STMicroelectronics is particularly relevant for this study since: 1) it is highly research driven. For instance, in 2012 the company spent about 28% of its revenue in R&D and its portfolio comprises 16000 patents, about 9000 patent families; 2) it is highly innovation driven. The successful examples of its innovative technologies comprise well-known microelectromechanical devices (MEMS), lab-on-chips, FDSOI that revolutionized various markets and created new uses. ST holds patents in several fields comprising circuit design, manufacturing process, packaging technology and system applications. Generally at ST patents describing new phenomenon discovery result from research activity. Moreover, conventional brainstorming, C-sketch of 6-3-5 methods are used solve technical problems resulting in patents. Each idea, once elaborated, is presented to the special patent committee, which evaluate the ideas, help to enrich them and decide whether the patent application process can be pursued. The panel of committee members includes various ST experts, IP engineers and external IP examiners.

Each experiment was conducted during 3 – 6 months period with teams in charge of developing relevant technological blocks. Teams comprised engineers, researchers, doctoral students who participated in inventions' generation. Coordinator and facilitators were in charge of deploying the method and control the quality of the corresponding proposals. The issued propositions were later discussed and presented to the patent committee. The experiments have resulted in a number of inventions and patent proposals were filled.

The experiment starts by defining A, E, K and introducing new words that enable to explore new design space (see Figure 4). These new words help to structure Knowledge space (in a C-K model). We will illustrate here three types of partitioning that teams were

able to come up with. The whole process of C-K exploration in case of patents cannot be exhibited here due to the confidentiality issues.

Patent first by keeping (A-E) but changing their relations

We illustrate how the design team that worked on multi-touch haptic solutions where touch was considered as a way of interactive communications to illustrate these strategies (Figure 5). The initial concept was formulated as “haptic touch as a way of interactive communication”. A team pursued the axis to improve and find alternatives to the already emerging solutions that consider haptic feedback. Here the work is based on new types of (A-E) relations. The already existing (A – E) sets were identified: electroactive polymers for volume rendering. Electroactive polymers (A) exhibit shape or size change in response to the electrical stimulation and allow independent volume rendering (E) (Figure 6). Here A, E can be considered known and the team was able to redefine the existing relation by bringing it to the new context, creating new knowledge - $\delta K(A, E)$.

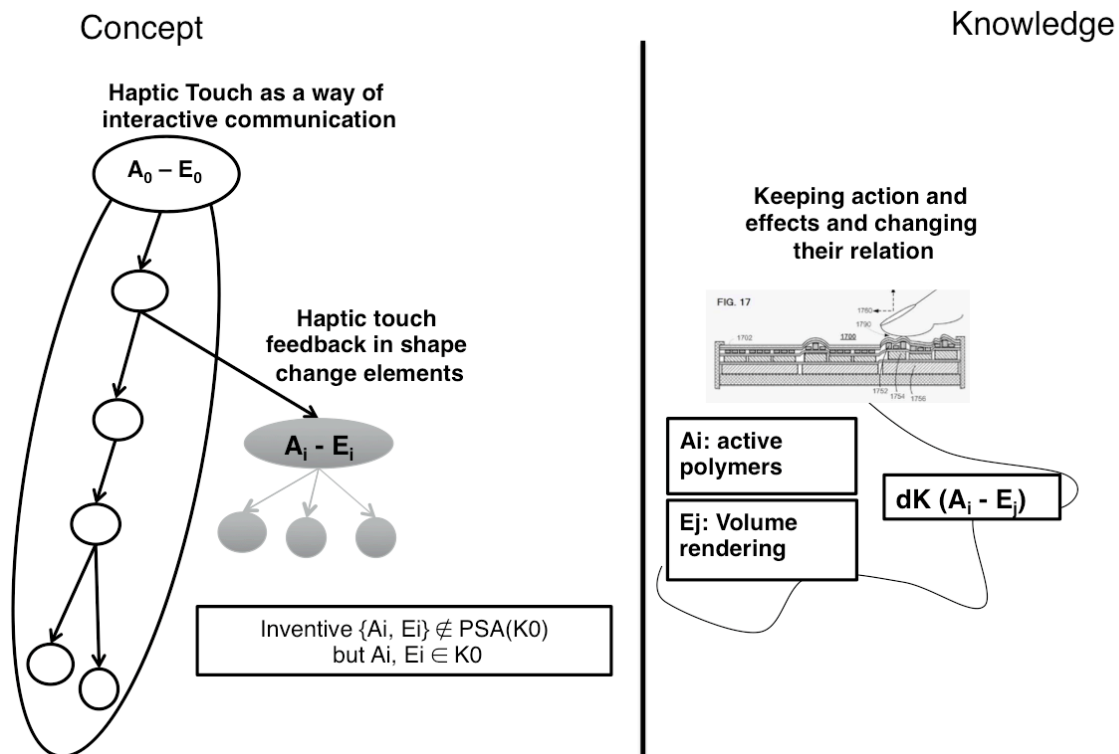


Figure 5: Patent design: creation new relations between action and effects

Creating new action for the existing effect

The team added new Action – flexible electronics using Organic Light-Emitting Diode (OLED) or graphene sheet (Figure 6). The haptic multitouch domain did not previously consider these actions. The team aimed to explore potentially disruptive solutions that account for capacitive multitouch flexible transparent display solutions. The desired effect was to achieve rich and precise multitouch feedback despite the screen flexibility. As a result the design team proposed inventions that deal with the innovative fabrication processes. They created new, disruptive (A, E, K) combinations and their starting point included an Action that was completely new and not evident for PSA. The team explored radical concepts in this case.

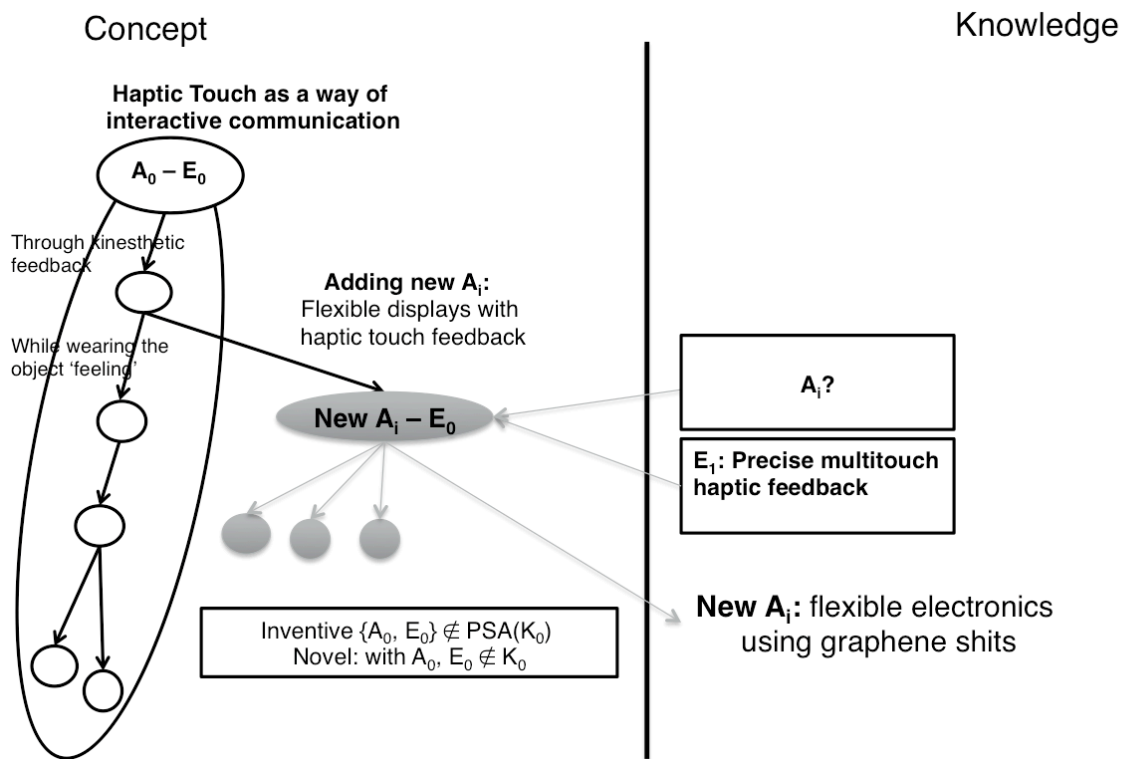


Figure 6: Patent design: creating new action

Creating new effect for the existing action

A team in this case was exploring a concept “3D Integration that have better electrical and thermal behavior than 2D alternatives”. TSV (Through Silicon Via) was already used as an existing solution to ensure electrical interconnections. By working on the generative concepts like “Design TXV that have better electrical and thermal behavior than 2D alternatives” allowed a team considering any type of substrate and ways of

interconnecting devices through this substrate (Figure 7). In this kind of concept the first part describes A (Action) which consists in realizing Via (drilling, etching, etc.) through a generic substrate (X which can be Silicon or any type of substrate such as AsGa,...). The second part of the concept describes E (Effects) that are expected from device behavior (electrical, thermal, etc.). For TXV new type of effects was considered – using them for better thermal management – thus, adding new effect.

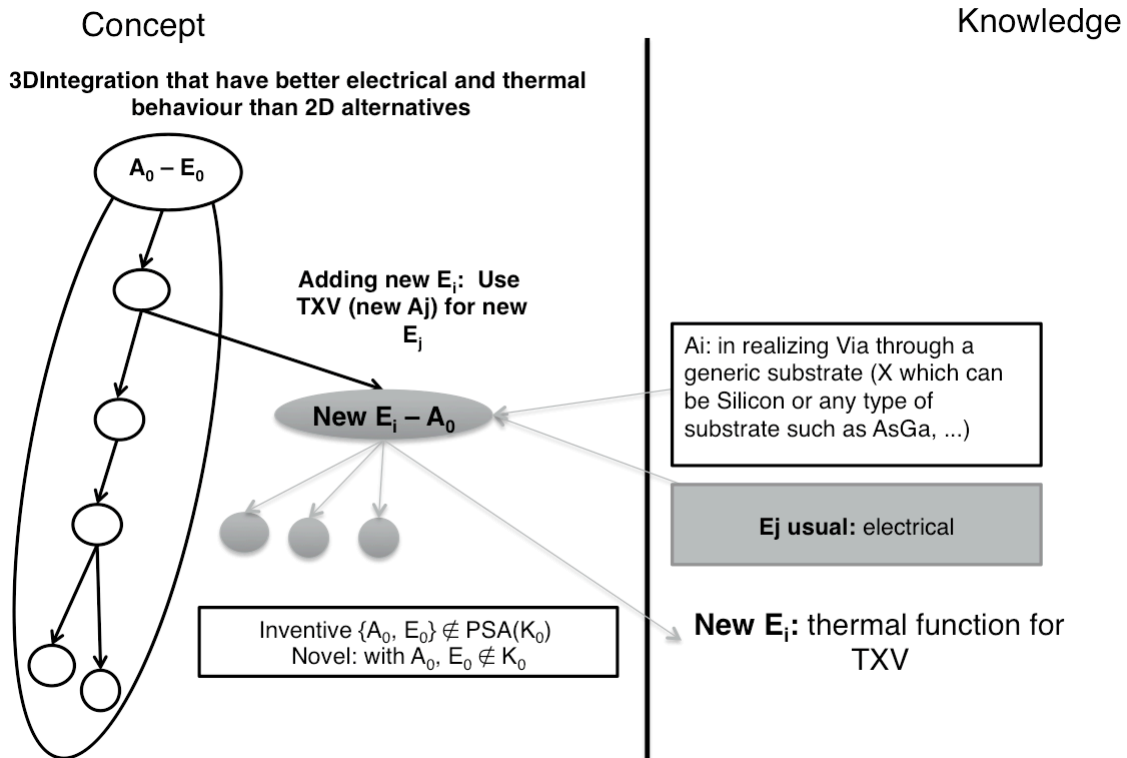


Figure 7: Patent design: creating new effect

4. ANALYSING PATENT DESIGN METHODS WITH PATENT DESIGN MODEL

Each design method described in Section 2 deals with patent design. Given a theoretical framework, do these methods consider patent model (in a form of A, E, K) and patentability criteria?

4.1. Comparison: how do we control for the $PSA(K_0)$

4.1.1. Technology first

Technology-first approach proved to maximally reuse the existing and developed new technology design rules. This approach is based on the existing knowledge and expertise

(K_0) that is already possessed by the company or is currently under development through R&D explorations. Patent model is not relevant in classical technology driven patent deposition. Therefore, this process is mostly driven by skills that exist in the field $PSA(K_0)$. Resulted inventions are based on the combination of the existing technological building blocks, existing knowledge and expertise ($PSA(K_0)$) to actually find new patent proposition. The knowledge expansion is deeply rooted to the existing expertise and thus harder to provoke. This is a more classical way of developing patents where the obtained proof of concepts results in patent filling (Ernst, 2003). Patentability criteria are examined by the patent engineers and are not usually verified during the technology design process. Patent examiner plays an important role on the claims definition, increases the importance of patent. He ‘designs’ patent proposal according to the common definition of PSA (see Table 3).

4.1.2. TRIZ

In TRIZ, a problem to engage in the design activity should be defined first. Contradiction theory in TRIZ defines a problem as a contradiction of systems parameters such as speed, size, weight. Novel combinations are based on contradictions between the existing actions and effects. In TRIZ, patent can be represented as (A, E, K) and matrixes give the guidance how to solve the problems and structure knowledge basis. Moreover, TRIZ gives indications on Concept-based strategy: it shows that one should start with the sets of (A-E) that are incomplete, with contradictions. TRIZ supposes to master the sophisticated knowledge since to define well a problem we need to know the extensive list of actions and effects. Moreover, TRIZ codifies the portfolio of existing patents. Thus, its inventive step and novelty are highly driven by the existing expertise and knowledge. It assumes a possibility of finding novel solution though a list of existing principles, which limits breakthrough character of invention. TRIZ does not directly incorporate patentability criteria (see Table 3).

4.1.3. Genetic algorithms

Genetic algorithm (GA) is a combinatorial strategy in K. It offers an automated evolutionary search based design process that is knowledge intensive and nondeterministic (Koza et al., 2004). In GA, the exploration space is defined in advance based in the genes sequences. Thus, all the actions and effects that can be used to achieve original

combinations are known in advance. It is not possible to create new actions or effects, to expand the existing K-basis. The patent design process corresponds to the original combinations of the existing genes that can be described as actions and effects. The original combinations are achieved thanks to the operators of crossover, mutation, gene duplication, deletion. The strategy in C-space is absent (see Table 3). The novelty and inventive step are thus limited since knowledge expansion is limited. GA is based on a limited version of PSA(K0). As shown in (Koza et al., 2004), genetically evolved tuning rules and controllers satisfy the statutory requirements on being improved and useful. Authors claim that these features would never occur to an experienced control engineer, they are unobvious to someone having ‘ordinary skills in the art’. As in a variety of legal frameworks (see section 2), PSA is defined differently and has different skills, the requirements to ensure novelty and inventive steps vary and thus, proposals created using GA can result in issued patents.

4.1.4. Design analogy

In design analogy system is based on the assumption that similar problems occur between different technologies with similar functions and properties. Design analogy is based on mining of problem-solved concepts, construction of the patent mapping and specification of the reference patents (Jeong and Kim, 2014). The authors claim that the method can be used for problem identification in case of new technology. Still the new technology should have the properties of the existing one. Otherwise analogy cannot be built. Design analogy can describe a patent proposal in the form of (A,E,K) where action and effects correspond to functions and properties. According to this method, the inventor should analyze the patents according to their similarities in functions (effects) and properties (actions) and decide which one can be transposable to a new domain (e.g., between router and charger in the given example). With this reasoning we cannot control for concept generation; we start by exploring and generating new K and hope to generate new concepts but there is no indication on how to do it and the patentability criteria are not ensured (see Table 3). The authors mention that their system is not applicable to novel properties or functions. Thus, Design analogy similar to GA is driven by K-space.

4.1.5. CK Invent: inventive step to create new actions, effects

The model of patent design enriched CK Invent methodology by 1) considering patentability criteria; 2) incorporating reasoning of PSA and 3) introducing three types of strategies (partitions) that allow controlling the type of desired invention.

Table 3 Patent design model

Method	Strategy in C- space	Strategy in K-space
Technology first	No control of concept space	K driven strategy
TRIZ (Altshuller, 1999b)	Strategy based on A/E contradictions	A, E, K
Genetic programming to automatically synthesize complete designs (Koza et al., 2005)	No control of concept space	A, E, K; K driven strategy
Design analogy method (Jeong and Kim, 2014)	No control of concept space	A, E, K; K driven strategy
CK Invent (Felk et al., 2011)	Strategy based on A, E expansions	A, E, K

All explored methods of patent design analyzed here take into account patent model in (A, E, K). Though, they lack knowledge on patentability criteria and do not take into account PSA reasoning. These methods mostly deal with the combinations of A, E, K but they do not discuss how to extend the reasoning PSA (K0), how to extend the initial combinations by creating new actions and effects and thus to expand the initial domain where PSA is capable to operate. There is no generation of new actions and effects and thus, the patentability is limited. In certain legal systems, the experts are based their evaluation on a limited number of combinations, these combinations can be considered novel. Though, from the design theory perspective, novelty is missing. This research reveals that there is a difference in resulted patent proposals on whether the exploration aims to define propositions as expansive partitions in C-space as in CK Invent or by exploring the existing design rules (based on K-space).

In addition, this research revealed that by starting with patent design first, an exploration team does not obtain the same results as starting with technology design first. Changing the order of partitioning influences the results that can be achieved: different alternatives and possibilities are observed and the design reasoning is different. Thus, the design theory does not always account for substitution meaning the order of concepts that appear in C-space influence the results of the future inventions. In practice, it means that the first-order concepts are important and will determine the future exploration and directions for knowledge production. By simply changing the order of the first- and second- order partitions, the designer will rarely end up obtaining the same results. In case a partition is driven by inventive character of patent proposals we target the expansive partition and thus, increase a probability of obtaining new original results.

5. RESULTS

The main research areas on IPs emerged through economic and legal literatures which can be too selective (Somaya, 2012). For instance, from the economic perspective patents are seen as economic indicators and address issues such as pricing, commercialization or exchange of the already established IP. Still major practical issue for the organizational structures that deal with the IP is its complexity (Gollin, 2008). There exist methods for patent design that allow for creative problem solving. Or more recently developed CK Invent method proposed an interesting way to design patents. This paper develops theoretical framework to incorporate patent design logic by building on the recent advances of the CK design theory.

The major results of this research are: 1) a model of patent design that takes in to account reasoning of person skilled in the art; 2) a comparison of patent design and characterization of their performance that depends on expansion from the existing knowledge combinations PSA (K_0); 3) a patent design model using C-K theory shows a non-substitution property that demonstrates that the order of partitions influence future results. This work demonstrates the irreversible power of operators in the C-K design theory.

A patent design consists of designing a new (A, E, K) that corresponds to Table 2. First, Patent design starts with the identification of the initial effects and actions with are referenced as $A_0 - E_0$; knowledge basis construction based on A, E, K and the definition of

PSA (K0) according to the countries where patent proposals will be filed. Second, the initial modeling of PSA (K0) should be extended, based on new A, E, or new relations between the A-E. This results in structuring the C-space. Third, a knowledge basis should be expanded which requires knowledge production to ensure conjunction. It means that once a new (A, E, K) that fulfills the patentability criteria is defined, knowledge production process begins to actually ensure proof of concept and develop technological proposition.

Thanks to a model of patent design, existing patent design approaches such as TRIZ, Genetic algorithms, patent design by analogy (Altshuller, 1999b, Felk et al., 2011, Jeong and Kim, 2014, Koza et al., 2004) are situated within the design process, their performance is compared. Traditional technology-first patent design (Ernst, 2003) process often produces the improvement patents that protect the differences between new products and already existing ones by adding new properties or substituting the old ones. The technology-first approach is suitable in case of dominant design where the goal is to propose better actions and effects to actually ongoing technology development. Patent - first method often results in a range of inventions facilitating creation of coherent patent portfolios. The use of patentability criteria interpreted with the help of design theory actually helps to reduce risks of non-relevance of the issued ideas. Different strategies of patent-first approach are examined. These strategies demonstrate that patents can be conditioned differently: the intermediary patent level that just works the relations between actions and effects, the patents that revolutionize and extend the list of known or ever used actions and effects. It expands both actions and effects enhancing the 'inventive' character of the proposal. In patent first approach there is a risk of non-relevance and thus, the process is controlled by patentability criteria and by company managers that can estimate the interest of the issued solutions internally. The ideas positioning according to the extended action and effects allows determining the design space and list the concepts that remain to be explored. Different strategies combined with patentability criteria increase patent propositions quality. Design reasoning that considers patentability criteria actually increases the quality of patent propositions. It shows the necessity to have various processes of ideas exploration regarding the available knowledge, the level of maturity, competition and offers the relevant patent exploration models.

The order of concepts that appear in C-space is not easily reversible; it conditions the success of the exploration and the corresponding results. This irreversible character leads to non-commutative character of the C-K design theory.

Overall, this paper proposes a better understanding of the legal and modeling aspects of IP and thus to better understand the conditions for patent design logic and the definition of person skilled in the art (PSA). In addition, better understanding of the PSA activity helps to take into account the criteria that explain the variety of legal frameworks. An inventor can be evaluated based on his capacity to create more or less important (A, E, K) combinations.

6. DISCUSSION AND PERSPECTIVES

This research proposes a model of patent design based on the C-K design theory. Patent model can be examined and enriched with other theoretical lenses like General Design Theory (Yoshikawa, 1985), Axiomatic Design (Suh, 1999), Coupled Design Process (Braha and Reich, 2003), Infused Design (Shai and Reich, 2004).

One might argue that patent design processes will increase the number of patents proposal to manage and thus, increase even more the IP complexity. Still the consequence of the method on the increasing number of IP is not evident since the goal is to seek for quality in patent proposals and not to augment the number of inventions.

Patent design model can be used to create cartography of the existing state of the art, better understand the dependencies between the existing patents. The use of action and effects to characterize the exiting technologies and patents, simplify the technological forecasting and allow identifying the interesting alternatives to explore, free zones to patent, automatically evaluate companies' position in accordance with the other actors. Keyword patent based maps allow to discover the unexplored areas and actually shape new discoveries, identify new technological opportunities (Lee et al., 2009).

Our work similarly to other patent design methods based on TRIZ depends on the strength of the group of experts participating in the experimentatuon work. Sill design theory formalism helps to guide reasoning and ensure inventive step and novelty of the emerging solutions. In their (Fu et al., 2015) propose patent-based functional analogy method which deals with these aspects of subjectivity. Patent mining techniques, patent mapping that aim

to use meta data or information in the texts of patents by analyzing patent databases can substantially enrich patents analysis to create databases of actions and effects. For instance, it might be interesting to use C-K with design by analogy search engines to first, use the power of the design-by-analogy search engine (Fu et al., 2015) to analyze functions embedded in the patent databases and second, experiment with new strategies of generating nonobvious ideas using C-K design framework.

In further work we plan to compare different patent design method on the same design concept and investigate overall effect of these methods to the novelty and inventivity of the proposed inventions.

The patent design model should be tested in case of platforms or generic technologies (Baldwin and Clark, 2006, Gawer, 2009, Gawer and Cusumano, 2008) which comprise both modules to address market complementarities and the core element of a technological system. How to protect the core? How the complementary innovations, modules should be patented? For instance, how to protect a platform core and better share (or not) the rights among platform designers? This is especially relevant in case of complex technologies where the property right is not exclusive but shared among the actors. In this case, companies built thickets of patents which obliges them to share rents under cross-licenses. In this case the structure of “patent thicket” should be carefully defined (Von Graevenitz et al., 2011). Yet the models for the design of such structures are missing. The design theory might provide new perspectives on this issue and provide new ways of designing interdependencies and associated revenue models to design relevant thickets. Patent thickets can be better designed.

Finally, IP is evolving and it can be seen as a competitive asset and as a mean to strategically create ecosystems of innovators. The design theory on IP management opens up new areas of research to seek new models for the strategic management of IP design for innovative ecosystems.

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