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Inventive Intellectual Corpus Analysis Applied to Incremental Technological Innovation

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Abstract

Our concern deals with the Knowledge Based Innovation domain in an industrial context. When a creative idea is generated, its transformation into new knowledge depends on a cycle associating three subsystems and highlighting the link between idea and knowledge: the individual who generated the idea, the knowledge field which acts as a reference repository and the knowledge community who evaluates, selects and validates relevant ideas.

Usual innovation dynamic is based on creative problem solving (from problem to solution). This paper covers the reversibility of the link idea-knowledge, that is to say the passage from knowledge to inventive idea. We promote an *ab nihilo* innovation dynamic (from ideation to innovation). In this paper, we propose an inventive idea generation method which takes advantage of the inventive intellectual Corpus of Knowledge actors. The research is dedicated to the epistemic connection between the structural analysis of knowledge contained in inventive intellectual Corpus and the ideation seen as inventive knowledge generation.

Our methodology consists in building a theoretical representative model and in validating it through experimentation. Model's input data represent a cognitive stimulus and model's output data consist of a prospective vision. Cognitive stimulus is based on in-depth analysis of the texture of knowledge structuring the inventive intellectual Corpus.

Results include experimental validation of the Knowledge Based Innovation approach. Our contribution consists in showing that ideation, stimulated by the critical analysis of the structure of knowledge lying in the knowledge actor's inventive intellectual Corpus, can be seen as an epistemic mutation, where source, process, results, corpus and knowledge actor can be assimilated as a unique entity.

An illustration of possible software implementation is given, derived from existing KM extraction software suite.

Key words: Stimulated creativity, Intellectual Corpus Analysis, Knowledge based innovation, KM analysis tool

1. Introduction

Firms' strategy is now based on innovation. The innovative activity highlights the ability of firms to maintain their competitive advantage. According to (Drucker 1985), innovation consists in looking for change in a determined and organized manner and in systematically analyzing opportunities which such changes can bring in terms of economic and social progress (Prax, Buisson et al. 2005). We can see that the innovation concept sends us to multiple research fields belonging to firm strategy, to marketing or to project management (Soparnot and Stevens, 2007). The word Innovation has several meanings, which can represent either the creative process able to generate a new element having an economic and social value, either the acceptance of this element by a community, either this element itself (Fernex-Walch and Romon, 2006). Our concern takes place in the new domain of Knowledge Based Innovation (Amidon, 2001): we want to highlight the link between Knowledge and Ideation in the sense of creation, formalization and sequencing of inventive ideas according to an intellectual process that structures a conceptual seed in a reasoned way (Saulais, 2015b). We can see that the link between idea and knowledge comes from the very principle of validation. Our questioning

regards the reversibility of the idea-knowledge link, that is to say the way from knowledge to inventive idea. Our research question can be expressed as follows: which epistemic connection can we make between the analysis of the structure of the knowledge included in the inventive intellectual Corpus and ideation in the sense of inventive Knowledge creation?

2. State of the Art and conceptual framework

2.1 Knowledge capital and inventive intellectual Corpus

According to a conventional approach of knowledge capital (Ermine, 2003), there is confusion between capital and Corpus. Our own analysis consists in discriminating capital from Corpus (Saulais, 2013). So, leaning on the Intellectual Property Code, we consider a capital as a group of assets able to generate revenue and an intangible capital as a group of intangible assets (Saulais, 2013). An invention patent is made of an intellectual content, which, when meeting patenting requirements, gives a property act to its owner: intellectual content belongs to Corpus and property act belongs to capital (Saulais, 2013; Saulais, 2014). With its dematerialized nature, Inventive intellectual Corpus is made of existing or recently acquired Knowledge specific to an individual and able to generate intellectual property rights (Saulais, 2013; Saulais, 2015b).

2.2 State of the art of innovation process

In this section, we will focus on industrial state of the art then on academic state of the art of innovation process.

Industrial state of the art

In the industrial world in general, innovation process follows the « pipeline » model (Figure 1). This innovation model comes from the development model called « Development Funnel » (Wheelwright et Clark, 1992).

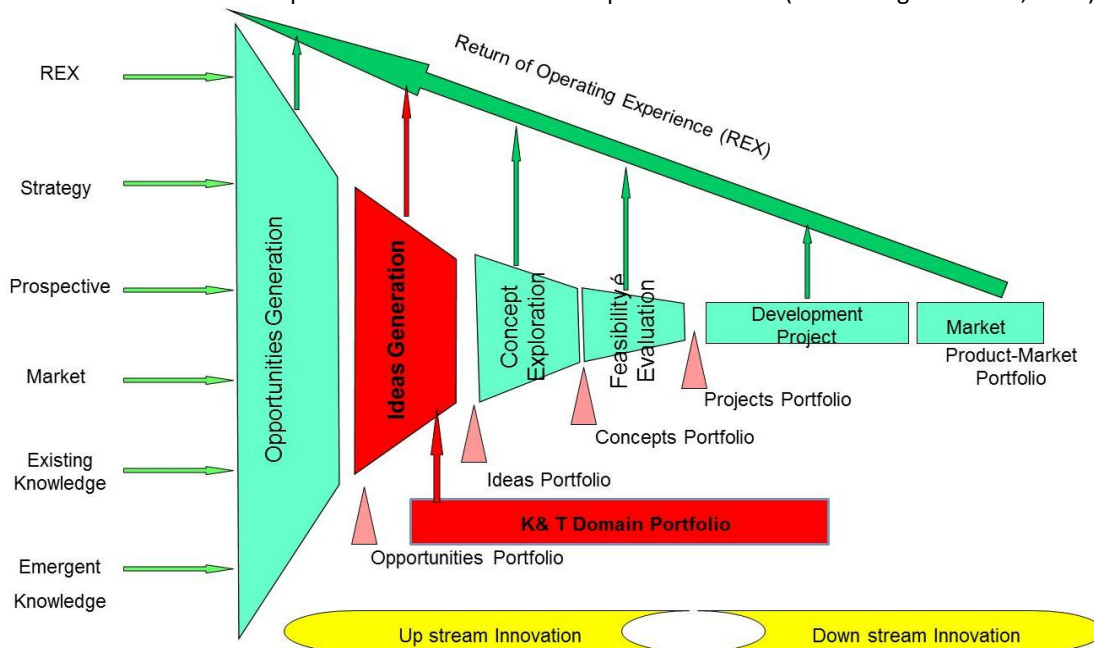


Figure 1: The pipeline model for innovation according to Gidel (2004) *Instrumentation du management multi-projects*, cited in (Fernez-Walch et Romon, 2006)

A recent study conducted by the *Club Gestion des Connaissances*¹ proposed a synthesis of numerous innovation methods used in firms: it shows that all these methods approximately follow the same process (Figure 2):

¹ French industrial association for KM diffusion, founded by Jean-Louis Ermine in 1999

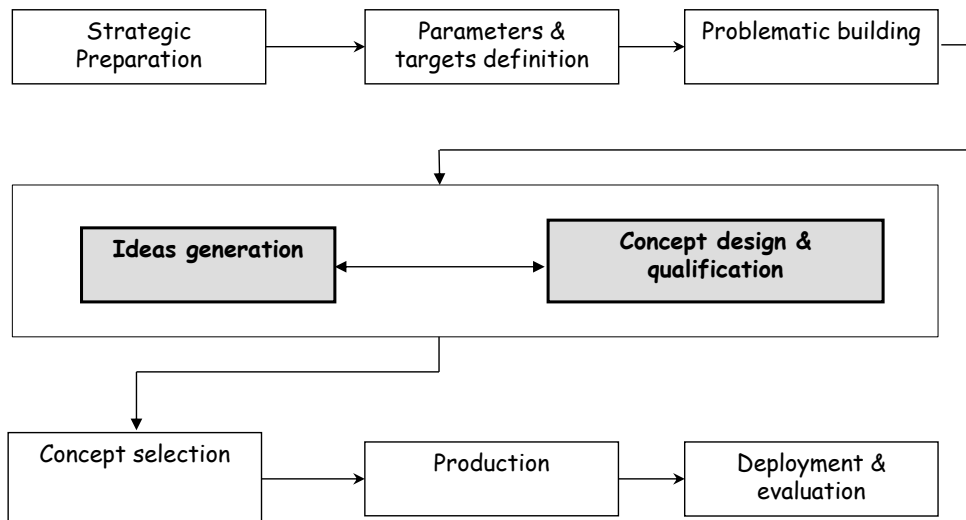


Figure 2: Innovation process

In an industrial context, technical innovation activity schematically depends on two innovation dynamics:

- Confrontation with a given technical problem requiring an innovative solving. It's a closed innovation process where the framework is the problem itself (Figure 3) ;
- The idea which having found a market. It's an open innovation process (Figure 4).

In Figure 3, reflexivity context is given from outside towards engineering team. This kind of innovation dynamic works on a "heteronomic" mode (which extracts its rules from outside).

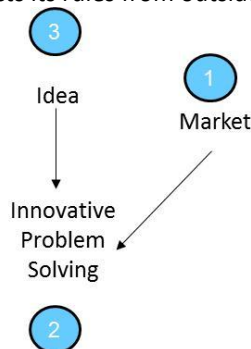


Figure 3: From problem towards solution

In Figure 4, reflexivity context is given from outside towards inside. This kind of innovation dynamic works on an "autonomic" mode (which gives rules for itself).

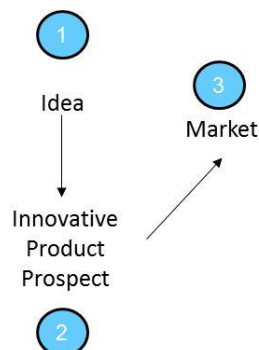


Figure 4: From ideation towards innovation

In both cases, innovation activities are leaned on ideas production, which are the essential resource. Classical creativity methods are matched to the first innovation dynamic which is problem-solving oriented. We can legitimately explore the innovation dynamic described in Figure 4, powered by new ideas generation issued from the analysis of existing intellectual Corpus.

Academic state of the art

Fernez-Walch and Romon (2006) suggest height different conceptual aspects for the innovation process: valorization of technical progress, acceptance of a new product, whirling process, marketing plan, political process, technical system transformation, learning process.

Innovation process management has multiple dimensions: (Trott 2004) highlighted product innovation management, (Van Stamm 2003) and (Bruce & Bessants 2001) insisted on design. Several literature compilations cover this field, among which the best known is directed towards the United States (Burgerman, Christensen et al. 2004). (Tidd, Bessant et al. 2006) also show how firms are inevitably limited in their innovation strategies by their past and current abilities.

Furthermore, a Knowledge Management approach can be included in the innovation process management: Debra Amidon (2001) locates the innovation power in the intellectual Corpus, coming from the combination of a quick share of knowledge and of the new applications evolution applications.

2.3 Use of knowledge for the research of innovative solutions

Innovation process can usually be described in four steps (Louafa and Perret, 2008): question description, divergent ideas production, convergence of generated ideas towards the given question, selection and choice.

Current techniques for divergent ideas production aim at generating as many ideas as possible in a given restricted time by stimulating imagination. Creativity methods aim at modifying knowledge by adapting them, recombining them, giving them another sense and another value (Louafa and Perret, 2008).

Using knowledge to discover innovative solutions is already part of some industrial design methods:

- The TRIZ method (« Theory of Resolution of Inventive Problems ») is dedicated to the resolution of technical problems requiring innovative solutions (Altshuller, 1984) ;
- The C-K (Concept-Knowledge) Theory: (Hatchuel and Weil, 2009) developed the C-K Theory in design engineering in order to formalize a real approach of creative design. It's one of the present examples of an approach based on Knowledge.

In the present paper, considering that « inventive design » is not the vocation of the method we developed but only one of its effects, we proposed to develop a Chaotic-inspired evolution model for knowledge (section 4).

2.4 State of the art in terms of models

We borrow to Jean-Louis Ermine (2003) the principle of the model basis (Figure 5 and Figure 6) described through steps 1 to 4. We wish to briefly recall how this basis is built. Building of the existing part of the model may be described as follows:

Step 1: Knowledge is part of a complex system

Aiming at conciliating connections between the all and the parts and at taking into account the complexity of the phenomenon under study, the Systems Theory progressively integrated every domain of knowledge, as Edgar Morin clearly shown (Morin 2008c).

Step 2: Knowledge creation is seen as an evolution of the knowledge system

In the Theory of Complexity, emergence characterizes the spontaneous apparition of a new structure in the considered medium, which cannot be explained by a simple combination of elements or of processes structuring the medium (Heudin, 1998). According to the Evolution Theory, Knowledge capital is not fixed but it follows a constant and fast evolution (Ermine 2003). A very important assumption in the innovation domain comes from economics through the « path dependency » assumption (David et Foray, 1992), for which innovation is an « endogenous and cumulative technological creation » mechanism.

(Ermine, 2003) proposed another method based on Knowledge (Figure 5), with two steps (analysis of Knowledge corpus and discovery of innovation well and innovation laws).

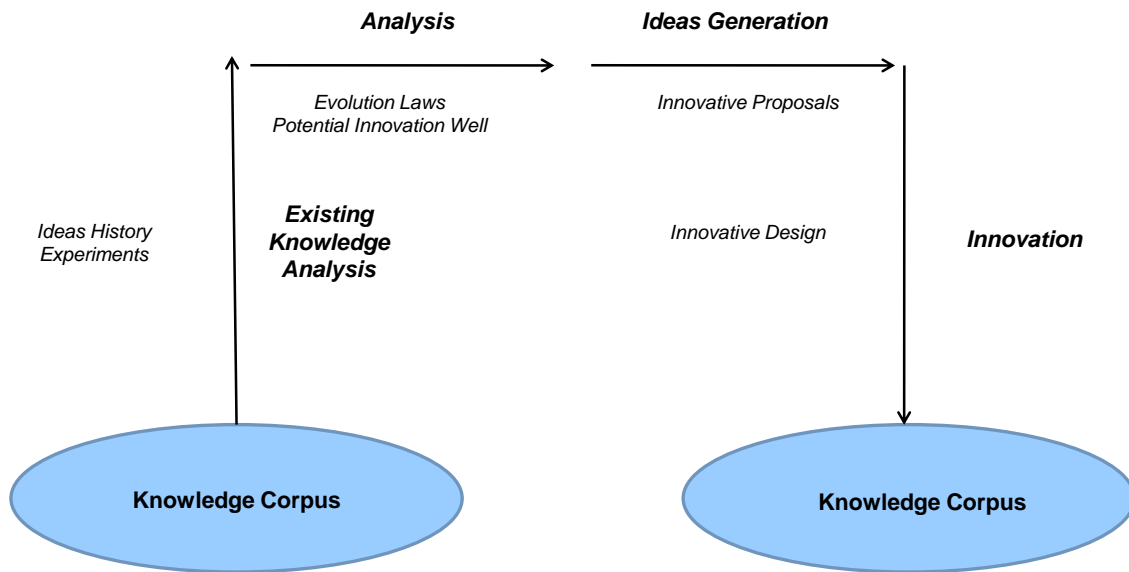


Figure 5: Innovative Knowledge creation process

Elaboration of evolution laws from knowledge drill (Figure 5) presents some analogy with innovation creation by recombination, either through knowledge brokerage (Hargadon, 1998 ; Hargadon & Sutton 2003), elements association in innovations distribution in order to prepare a rupture (Fleming, 2007), recombination of innovations (Fleming, 2001), combination of new knowledge and existing knowledge (Nerkar, 2003).

Step 3: Thanks to the path dependency assumption, we postulate that knowledge evolution seen as complex system can be described by another complex system

The path dependency hypothesis explains the strategic diversifications of the firms and it can also explain how innovations appear in organizations. Existing knowledge are conditioning future ideas leading to innovation, which fits Cohendet and Llerena (1999) who consider the firm as a knowledge processor.

To sum up, the hypothesis made by Jean-Louis Ermine consists in the assimilation of the knowledge creation process to the firm knowledge capital evolution process, based on the creativity of the knowledge actors, inside the firm but in interaction with their environment.

Step 4: The evolution process can be generalized to any time-dependent complex system

A general evolution model can be derived from the analysis of emergence in biological systems (Heudin, 1998). A system is built on structures which may vary when some energy is brought to the system. This transformation is regulated by the feedback which confronts these structures with their environment. The finality of these structures is expressed in terms of properties. When transformed, these structures get new properties. The evolution process only keeps the property compliant with the system's finality, thanks to the stabilization loop. Rejected properties represent the system entropy. This operation of relevant properties creation is an emergence phenomenon since it represents a new and matched solution for the evolution of the system under analysis (Figure 6).

An analogy can be highlighted between creativity process and a process called « chaotic » (Gleick, 1987; Prigogine, 1996), characteristic of a divergence process. However, introducing a regulation loop allows the emergence of a stable structure by filtering the outputs generated by divergence: it's the emergence phenomenon. This structure is a new and matched solution to the given problem and so does the creativity problem.

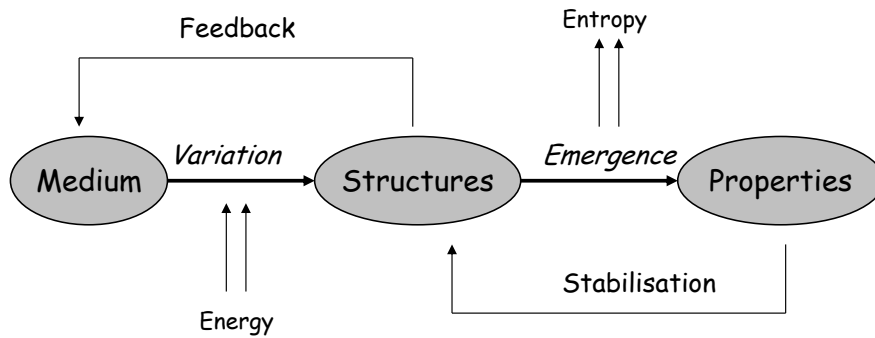


Figure 6: The general evolution model

To sum up, according to (Heudin, 1998), the evolution process can be generalized to any time-dependent complex system, thanks to four sub-processes: variation out of balance following energy supply, feedback, emergence and stabilization towards balance (Figure 6).

3. Methodology

Our methodology is based on experimental method, aiming at building a representative theoretical model (Figure 7) and at validating it by an experiment (section 5) using collected data.

According to Lalande (1926), experimental method really consists of observation, classification, hypothesis and validation by appropriate experiences. In other words, experimental method consists in inferring some observable consequences from a law, an hypothesis or a theory and, most often thanks to an observation and measurement process, in determining if these consequences fit facts or not.

For the theoretical model, input data are seen as a cognitive stimulus corresponding to the different temporal sections of the inventive Knowledge trajectories included in the inventive intellectual Corpus and output data are seen as a production materialized as a prospective vision. The experimentation instantiates the theoretical model thanks to individuals solicited as Knowledge actors (Figure 8).

4. Theoretical model

In previous section 2, we saw an initial model (Figure 6, steps 1 to 4 of section 2.4). Our contribution mainly includes step 5 (Figure 7) and step 6.

Step 5: The theory of Chaotic-inspired evolution by emergence can be applied to the creation of inventive knowledge

As we deal with a system facing evolution, we apply the general model of evolution to the creativity problem, thanks to already collected theoretical elements, in order to get the model of Chaotic-inspired model of inventive Knowledge by emergence (Figure 7).

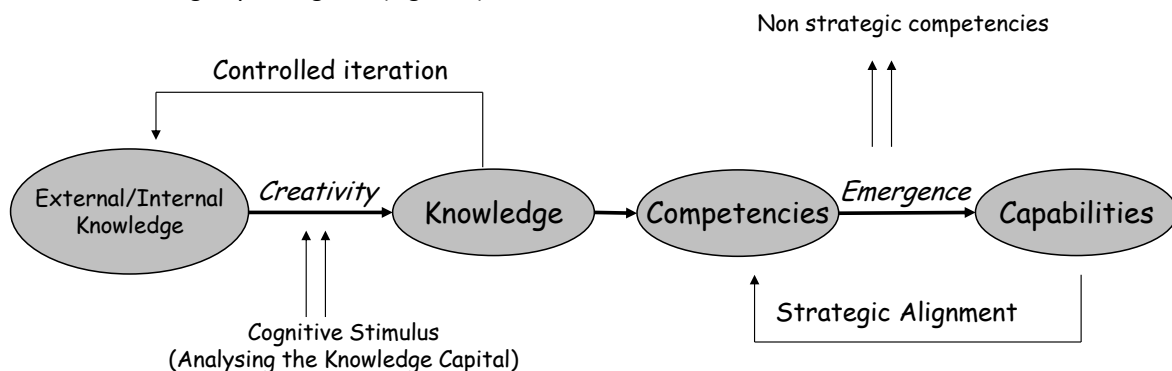


Figure 7: The Chaotic-inspired model of Knowledge evolution by emergence

Evolution can be modeled by a dynamic non-linear instable function, fitting the chaos approach by the second principle of thermodynamics: it's the reason why we called « Chaotic-inspired » the model (Figure 7) in order

to keep the link with thermodynamics. Then the fact of emergence shows itself as apparition of new qualities which can't be reduced nor deduced from the properties of initial components.

So, the Knowledge creation process can be represented as an instable non-linear dynamic system, unpredictable for the long term and based on the Second Principle of thermodynamics (Saulais and Ermine, 2011). According to the Chaotic reasoning, creativity starts with a kind of tension between the desire of evolving towards an upper form of organization (negentropy) and a statement of evolution towards a lower form of organization (entropy). This tension can free itself only by a conceptual idea (creativity), structured by reasoning into an invention idea to be concretized in an innovative product (Saulais, 2013).

According to Figure 7 model, organized Knowledge will be improved thanks to the cognitive stimulus. We think that the model described in Figure 7 is relevant to set up an operating mechanism of idea generation regulated, weighted and oriented towards the firm objectives, on which our *ICAROS*[®] method is based (See Step 6 below and section 5).

Step 6: Activation of Chaotic-inspired model of Knowledge evolution by emergence thanks to ICAROS[®] method

The *ICAROS*[®] (*Intellectual Corpus Analysis for Reasoned Openmindness Stimulation*) proposed stimulated creativity method aims at activating the Chaotic-inspired model of Knowledge evolution by emergence (Figure 7), from the creation of a cognitive stimulus: this cognitive stimulus is derived from the inventive Knowledge creation process illustrated in Figure 5 by limiting Knowledge Corpus to inventive intellectual Corpus: Knowledge actors represent experts organized in communities, carrying reference Knowledge both on external environment (markets, state of the art, ...) and on internal environment (specific tangible and intangible resources of the firm).

For our approach, we center our frame of reference on the Knowledge actor and not on the organization, as long as we focus on the upstream part of the creativity concept, which belongs to the individual (Saulais, 2013).

Our new use of inventive intellectual Corpus as dematerialized corpus directly comes from the mental scheme based on inventive Knowledge likely to generate intellectual property rights.

We note the attractive aspect of the representation of Knowledge creation as a result of a systemic evolution process, in the frame of order/disorder dialogic, of time irreversibility and of substitution of possibilities to certitudes: it's in probabilistic representations that creativity may find its place.

5. Thales case study

The objective of this section is to link the experimental procedure and the elements of the theoretical model.

5.1 Context

Stimulated creativity process uses current community, in the sense presented in the special issue of Management review (HEC-Montréal, 2010), organized in *Knowledge & Technology* Portfolio Domains.

5.2 Global presentation of stimulated creativity process

We now describe the creativity process as applied (Figure 8).

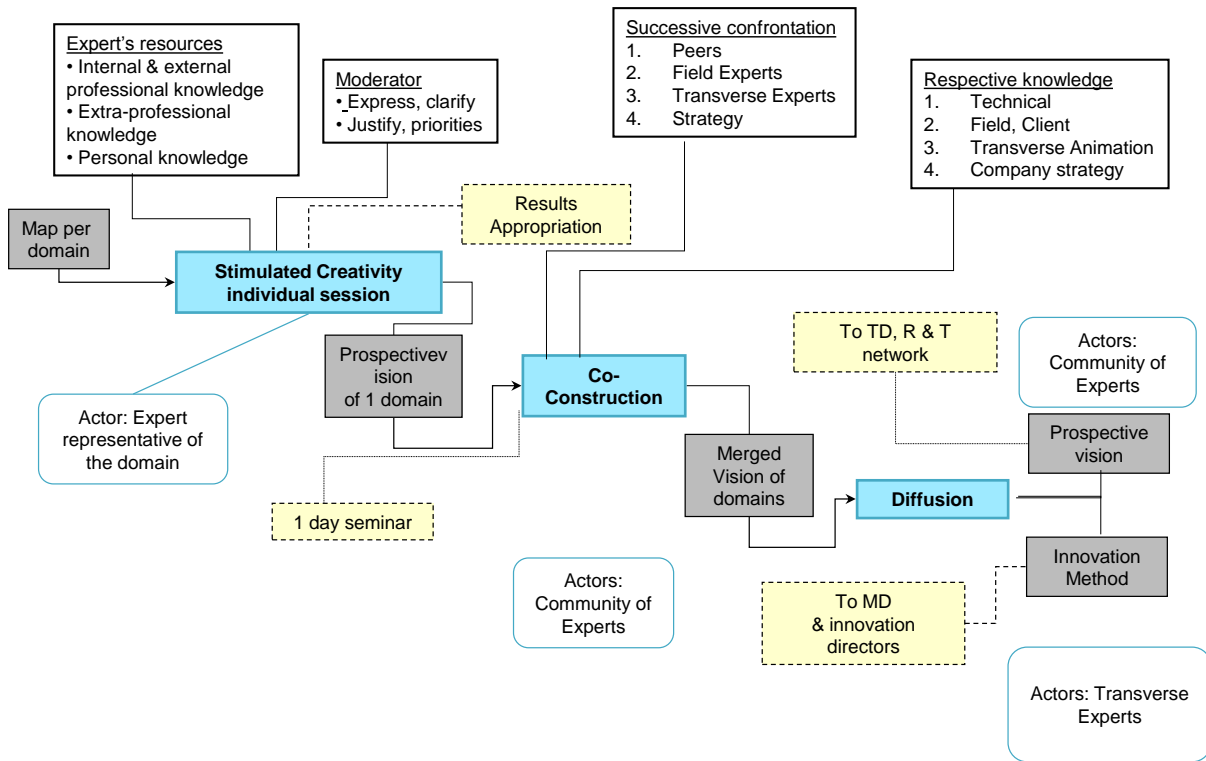


Figure 8: Knowledge based creativity process

5.3 Phase 1: Preliminary: Intellectual Corpus inventory

Figure 9 describes the methodology of the preliminary phase, consisting in the inventory of inventive tracks related to one Knowledge domain, projected onto a Knowledge map, which is the input of the creativity stimulation process.

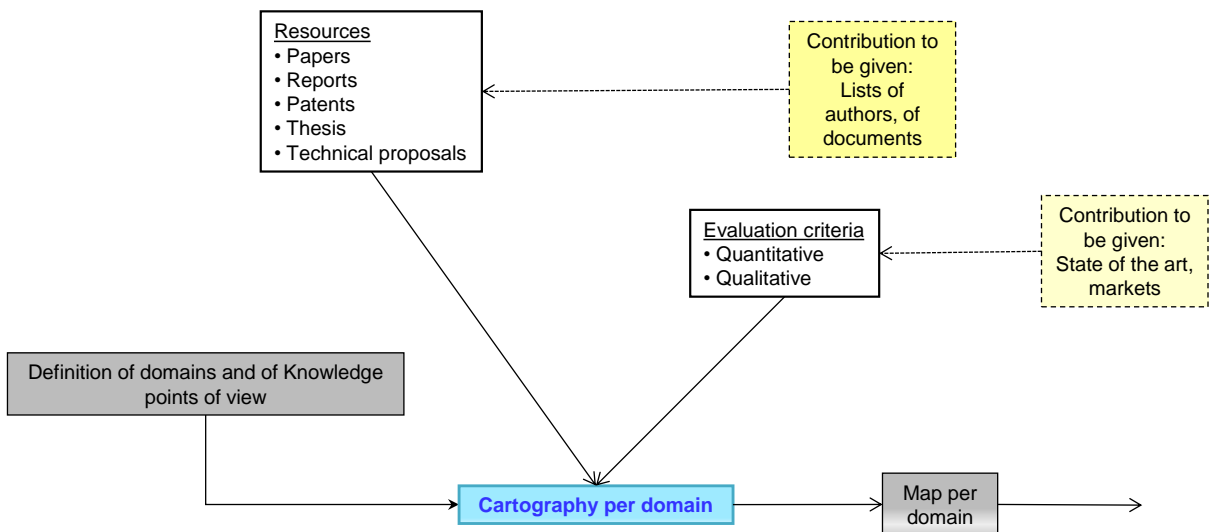


Figure 9: Preliminary Inventory

The firm develops and produces technical objects, presently surface radars. A technical object should not be seen through the organization / production processes prism, but as an autonomous *a priori object* which holds intrinsic Knowledge. This Knowledge must be described in a non-contextual language, available for many communities, even outside the organization. We decomposed the technical Radar object into ten technical domains. Each domain can be seen as a complex system (Bertalanffy, 1968), which is classically described according to systemic points of view: functional (what the systems does), structural (what the system is), teleological or applicative (what the system is designed for) and a genetic aspect (system evolution)

represented by the time axis of the other points of view. Figure 8 gives an example of cognitive map for the algorithm domain.

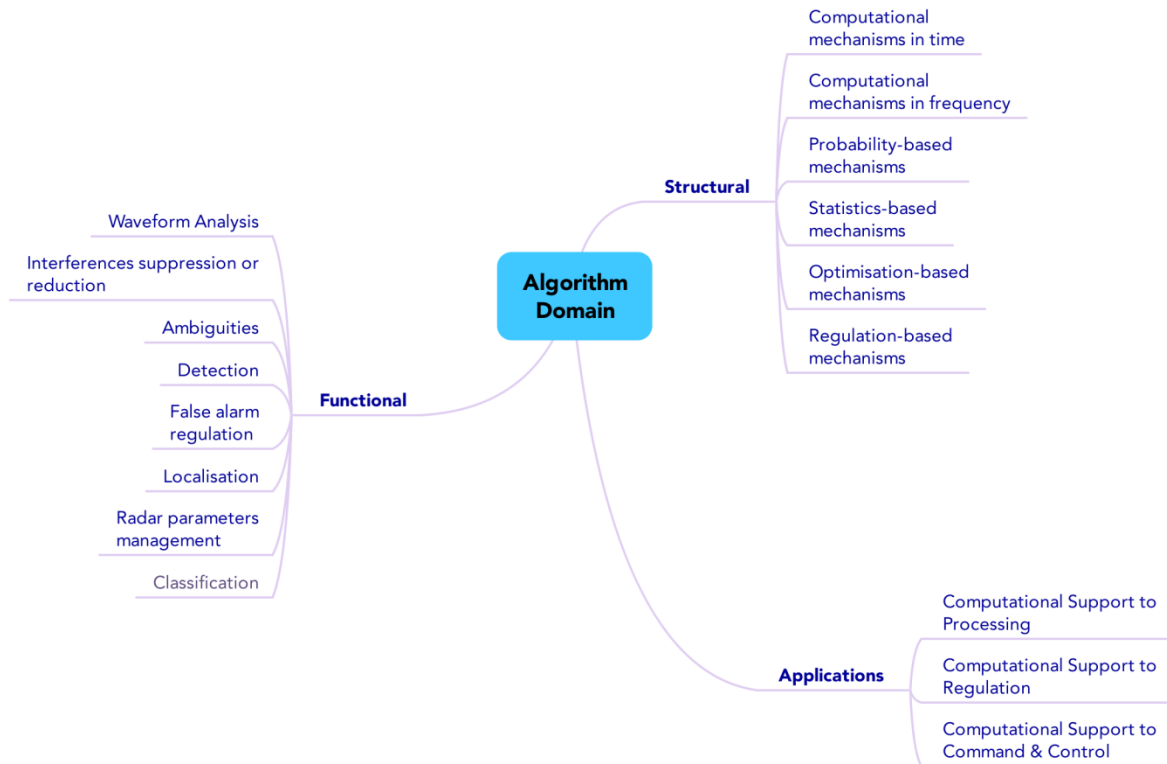


Figure 10: Example of cognitive map for the Algorithm domain

Preliminary work was dedicated to the inventory and to the analysis of the past inventive tracks. It was carried over by the author as completely and objectively as possible.

Tracks were collected during sixty-two individual interviews, for three technical domains, for a total of ninety three hours. Individual inventories are merged topic by topic to get the global inventive tracks.

Intellectual Corpus elements are the inventive dated tracks of the last thirty years (patents, articles and papers, study reports, internal memos and white papers, presentation slides, training material), projected onto knowledge map, analyzed and synthesized by the author.

Independently from the *ICAROS*[®] experiment on creativity stimulation, the inventory of inventive activity of more than sixty experts during the past three decades in the three main fields of the company and its reasoned synthesis leads to a large amount of strategic material that only very few companies search for resources to build.

5.4 Phase 2 (First loop of Figure 7): Individual creativity stimulation

Stimulated creativity individual sessions include the following steps: presentation to the expert of the tracks projected in the Knowledge map, analysis of the tracks by the expert and statement of his prospective vision for his domain. Each half-day long session was recorded.

During stimulated creativity individual session, each expert is requested to react to the representation of inventive tracks of past years in his own Knowledge domain. They must then determine how their own analysis of the past and present situation described in terms of dated inventive tracks could logically be transformed into a prospective view of what future inventive Knowledge are to be created or acquired. This prospective formalization of their vision of their Knowledge domain leads to motivated proposals of study projects to be candidates as inputs to the innovation procedure.

After a detailed analysis of the session records, a synthesis of each session led to a prospective document validated by the expert. All prospective documents are synthesized into a complete structured vision giving numerous axes to technical transverse strategic activity.

5.5 Phase 3 (Loop 2 of Figure 7: Collective co-building of prospective vision

Creativity stimulation process is applied to the entity Knowledge actors through three steps (Figure 10).

Initialization of this phase was performed by the redaction of the prospective document including all the proposals from each stimulated expert: the prospective elements provided by the creativity individual sessions were successively confronted to different groups, the technical peers, the technical field experts, the representatives of technical strategy and of the strategy of the organization.

The seminar report includes, for each domain the major R&T problems that determine the future stakes and the way to solve them.

5.6 Phase 4 (First loop of Figure 7): Diffusion of results

Phase 4 deals with the diffusion of results to dedicated actors as prospective vision shared by experts and by managers.

5.7 Results

Results include experimental validation of the *Knowledge-Based Innovation* approach:

- Inventive intellectual Corpus includes elements able to represent inventive trajectories linking inventive intellectual tracks (patents, advances studies reports). Inventory of individual inventive intellectual Corpus on several ten decades projected in inventive Knowledge maps allows to determine, understand and explicit the inventive trajectories ;
- A reasoned analysis of the tracks gives the intellectual progress along the tracks (acquisition of a method, in-depth analysis, questioning about variant, bifurcation and drop) ;
- Creation of numerous prospective elements from an in-depth reflection based on the analysis of the numerous different time segments of inventive Knowledge trajectories points out the emergence of new material able to improve inventive intellectual Corpus ;
- Creativity stimulation is firstly applied to Knowledge experts representing each their Knowledge domain. Creativity stimulation is used to help knowledge experts determining and clarifying their individual prospective elements in order to help them building a prospective vision of their domain.

Our contribution consisted in showing that ideation, stimulated by the critical analysis of the structure of Knowledge lying in the Knowledge actor's inventive intellectual Corpus, can be seen as an epistemic mutation, where source, process, results, Corpus and Knowledge actor can be assimilated as a unique entity.

5.8 Illustration of possible software implementation of ICAROS[®] method in IP Metrix[™] TKM software suite

IP Metrix[™] KM extraction software suite was developed by TKM (*TecKnowMetrix*), a spin-off² from Grenoble University Laboratory specialized in data mining applied to scientific and technological literature (analysis of heterogeneous corpus, data mining on huge quantities of data, automatic processing and normalization, parametric dashboards). This *KM* extraction software suite is dedicated to a simple firm environmental search or to an in-depth bibliographic analysis. Its heart is made of a very large Knowledge base (patents, scientific literature, technical literature, European projects, firm monographs) constantly updated and stored on a secured server.

Discussions are currently in progress between the two co-authors in order to include the *ICAROS*[®] method in *IP Metrix*[™] TKM software suite. Main idea is to implement some rise in Information Value Chain or *DIKW* chain (See Figure 11). *DIKW* chain is composed of Data, Information, Knowledge and Wisdom, defined as follows:

² TKM was launched by four researchers in 2004 following a very simple statement: main strategic decisions linked with innovation are based on interviews of experts but without preliminary control of information. However, one of the features of innovation process is the availability of this information: many information sources do exist, among which are patents, scientific literature but also technical literature, collaborative projects, web and so on

- Data: simple signs without intention
- Information: collection of organized data
- Knowledge: Information-based representation representing realities of the world
- Wisdom: ability to action structured Knowledge and comprehension in a reasoned way, in order to determine and reach creation objectives

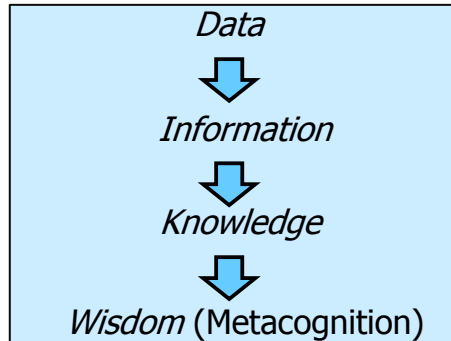


Figure 11: DIKW Value Chain

Considering the *IP Metrix™* TKM software suite as a relevant information processor and the *ICAROS®* method as a relevant ideation method for inventive activity, the co-authors' finality is to extend present capacities to achieve an implementation of a *Knowledge base*-supported software tool dedicated to inventive Knowledge generation (See Figure 12).

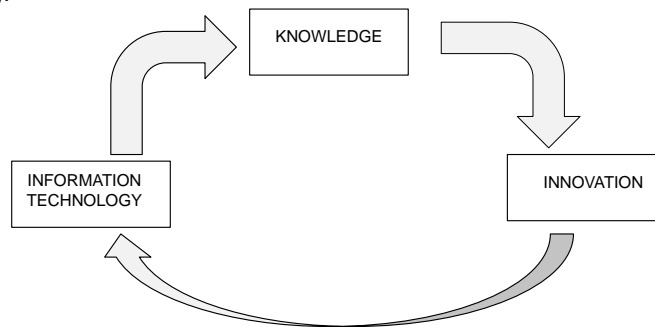


Figure 12: Role of IT in the KBI loop

5.9 Results discussion

With respect to literature, this paper gives numerous contributions. On one hand, it illustrates an experimental validation of *the Knowledge-Based Innovation (KBI)* method as described in section 5.6. On the other hand, theoretical results can be described as follows:

- Ideation is stimulated by the critical analysis of knowledge included in knowledge actor's inventive intellectual Corpus ;
- Ideation is seen as an epistemic mutation where source, process, results, Corpus and actor may be assimilated as a unique entity ;
- A new link was established between intellectual property domain (inventive intellectual Corpus), Knowledge management domain (cognitive stimulation based on the analysis of the structure of the knowledge included in inventive intellectual Corpus) and innovation management domain (creation of inventive Knowledge).

With respect to management practice, contributions of present paper lay on the demonstration that the *ICAROS®* method of ideation based on Knowledge is an alternative to open innovation, where the opening was made as a preliminary and where the approach through Knowledge highlights the fact that the prospective analysis is not applied on the product but on the structure of the Knowledge carried by the technical object considered as a Knowledge object. Furthermore, co-operation considered in a close future by the co-authors aims at improving management practice by achieving the implementation of a *Knowledge base*-supported software tool dedicated to inventive intellectual Corpus analysis and inventive Knowledge generation.

6. Conclusion

We described a theoretical model of emergence-evolution Knowledge and a structured method, *ICAROS*[®], based on the activation of this theoretical model of inventive Knowledge creation able to feed the innovation procedure. Our approach based on the dual concept of creation (creativity-inventivity) suggested that inventive Knowledge creators could be considered as the center of the method, after the prerequisite inventory of inventive activity and structuration of the inventive intellectual Corpus carried by the Knowledge actors.

In a financial context not favorable to internal R&D investments, in order to stimulate innovation, *Knowledge-Based Innovation* could be a very effective alternative to open innovation with its strong assumption of path dependency: it's the first degree of application of our method. The second degree of application of our *ICAROS*[®] method, based on the creative determination of which creative knowledge are to be acquired, is made of an epistemic mutation which represents a very promising research axis for an in-depth exploration.

Co-operation considered in a close future by the co-authors aims at improving management practice by achieving the implementation of a *Knowledge base*-supported software tool dedicated to inventive intellectual Corpus analysis and inventive Knowledge generation.

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