

# TOWARDS A COGNITIVE-INNOVATION ARCHETYPE

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**Abstract** - This paper proposes a Cognitive Innovation Model that formalizes the basic components and the interactions between them for the establishment of a Cognitive Architecture (CA). The convenience of walking in the sense of achieving an archetype as support for the implementation of intelligent solutions in real scenarios and having the client as a means of convenient validation of the representation and processing of the knowledge expressed in the CA in comparison with those executed by humans in their daily activities.

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**Keywords** - Cognitive Architecture, Cognitive Innovation Model, Knowledge Management, KMoS-Reload.

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## I. INTRODUCTION

Staying a live in a world in constant change, dynamically shaped by science, technology, nature, and society, implies people face many challenges, both individual and social, where innovation plays a vital role. Our current technological world uses a lot of pieces of knowledge, this means high valuable information, useful to solve a problem or satisfy a particular need. Thus, the satisfaction of who has the problem or need is achieved when the knowledge is capitalized by Cognitive & Innovative Solutions (CgI-S). Hence the importance of finding how to use and take advantage of as much of creative expertise as possible; either to use it in a systematic way or with the intention of sharing. Dominating this challenge is a fundamental key for the cognitive era<sup>1</sup> to progress. In the cognitive era, Cognitive Architects(Cg.Ar) together with specialists from the domain to be treated make up the Cognitive & Innovative Solutions Architects & Providers team(CgI-SAPteam) to provide CgI-S using highly specialized information, experience, creativity... coming from an ad hoc Collaborative Network(ahCN); which allows the team to do an adequate job even with innovation. In addition, the CgI-SAP team applies science and technology to take advantage of this knowledge in order to achieve the Capitalization of Experience or Knowledge in solutions or innovation. It is undeniable that the above represents a complex situation [1], [2] since it requires a complete orchestration of the process, on the part of the Cg.Ar. This document is an effort to match situations or needs that should be faced with intelligent technologies and innovation processes, at times when the environment is extremely dynamic being this characteristic very typical within what is now called cognitive era. The above motivates to provide a Conceptual Model of Cognitive-Innovation(CgI-M) as an Archetype that has a formal support that consists of the Systematic Process for Knowledge Management(KMoS-REload); which formalizes the interaction between an ahCN, a Cognitive Architecture, and the CgI-S implementation process or particular treatment. The remainder of this paper is structured as follows: In Section §2 sensitive

concepts and related work to the subject are described. A general proposal Conceptual Model of Cognitive Innovation is presented in Section §3 where also the ad hoc Collaborative Network, the Cognitive Architecture, and the dynamics of the KMoS-REload process and its main characteristics are presented. As an application, Section §4 introduces the start-up of the KMoS-REload process through a client study to describe the benefits of using the Conceptual Model of Cognitive Innovation and presents results of this study. A brief discussion is given in Section §5. Finally, the conclusion and future challenges are presented in Section §6.

### A. Informally Structured Domain

Generally, who suffers from a situation, problem or need, belonging to the cognitive era, is aware of this situation but does not have the time, ability, or knowledge to determine the nature of the problem and less to give the appropriate treatment or implement actions that resolve it because the activities related to the dynamics and environment of the problem are constantly changing, which implies that the problem cannot be stopped. The organization and processes of such activities could be carried out in acceptable conditions, but to survive in the current environment, innovation is required. This innovation must start from the fact that the knowledge of the environment is uncertain, ambiguous...and only some decision makers and specialists in the domain have it but incomplete and with different degrees of specificity. This domain is an Informal Structure Domain (ISD) and can be described by characteristics of how are its data, information and knowledge, and how are the representation and communication between them in the following way: heterogeneous data and information; specialized knowledge with a high degree of informality, partial and non-homogeneous; and knowledge that is mostly tacit and without structure. In addition, the ISD interacts with an ahCN that must understand the problem, need or business, identify application opportunities and obtain the knowledge requirements of this intricate knowledge ecosystem to propose a convenient, viable and valuable CgI-S. In Fig.1 an ISD is characterized by exemplifying the context or environment of whoever requires a CgI-S.

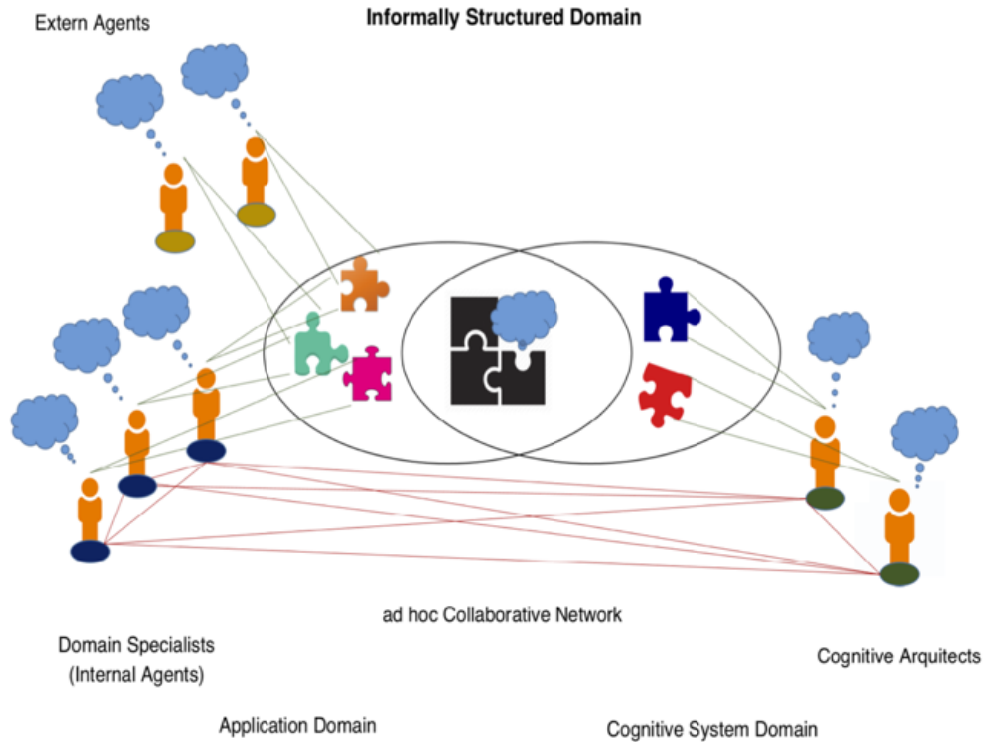


Figure 1. An overview of ISD's Eco System

Finally, in the context of the ISD, in particular, the External Knowledge under the business concept must include the market and consumers; it is very important to understand from the beginning of the user experience under the integration approach of a value chain. That is, now to be able to add value in a value chain, it is not only necessary to understand the dynamics of the companies that are served, but the factors that motivate their respective market niches.

### B. Innovation Process

Innovation is the change or series of changes through inventions that will always improve and add value to a product, a process, or service...The innovation can occur incrementally or disruptively and has to be tangible in the same process, or product or service resulting from it. Therefore, an innovation process is important due to:

- Opportunities for problem-solving: When innovation is fostered, brainstorming arise from attempts to solve existing problems or needs.
- Adapting to change: In the technological world where the environment changes drastically, change is in- evitable and innovation is the means, not only to keep a company afloat, but also to ensure that it remains relevant and profitable.
- Maximization of globalization: Innovation is a necessity to solve the needs and challenges and take advantage of the opportunities that open markets around the world.
- Be in competition: Innovation can help establish or maintain the vanguard of a company, compete strategically within a dynamic world and make strategic moves to overcome the competition.

- Evolution of the dynamics of the workplace: Innovation is essential for the use of demographic data in the workplace, which constantly change, and ensure the proper functioning of the product, service or process.
- Knowing the changing desires and preferences of clients: Currently clients have a wide variety of products, services or processes at their disposal and are well informed to make their choices. Therefore, it is imperative to keep up with changing tastes and also forge new ways to satisfy the clients.

## II. PROCEDURE FOR PAPER SUBMISSION

In this section, the CgI-M model is presented as a starting point to achieve an archetype: an original mold, or pattern, that links the process where elements or ideas intervene in order to establish an architecture to support a Cognitive Solution... a Cognitive Innovation. The archetype proposes models of knowledge representation that include experiences, behaviors and ways of thinking, collectively shared, which are constructed from theoretical tools—by imitation or similarity to human ones—assimilating and codifying knowledge, defining the existing relationships between concepts of the Informally Structured Domain given. Consequently, the archetype produces a physical or symbolic solution, tangible or intangible things or processes, or parts of them, that could generate something more of themselves. Figure 2 shows a general outline of the CgI-M model.

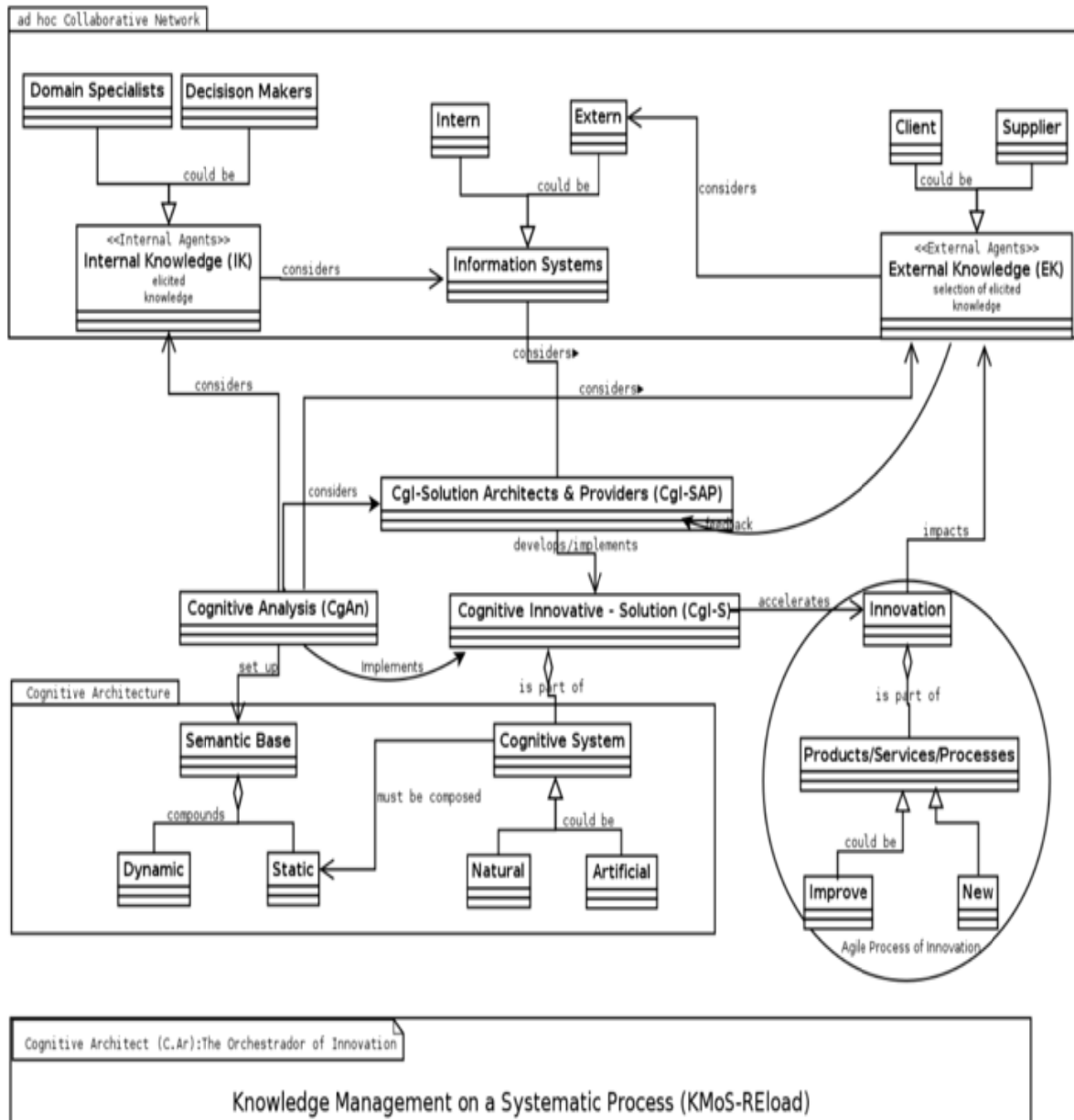


Figure 2. A Cognitive &amp; Innovation Model

It is important to indicate that the CgI-M model is open, constantly revised, enriched, updated, and that it is currently implemented as a modus operandi of a Cognitive Architects team to build Cognitive Solutions.

Subsequent subsections give a review of the parts of the model.

#### A. ad hoc Collaborative Network

As previously pointed out, cognitive innovations use creative experience or specialized knowledge from various sources that can be entities, agents, systems...who possess knowledge or information, and together set up an ad hoc Collaborative Network (ahCN). An ahCN is compounded by a triplet

$$\text{ahCN} = (\text{IA}, \text{IS}, \text{EA}) \quad (1)$$

Equation 1: The ahCN is equivalent to a triplet compounded of knowledge or information sources,

internal or external, from a given domainwhere:

- Internal and External Knowledge (IK & EK) are pieces of Knowledge or Experiences<sup>3</sup> that are present in the Informally Structured Domains (ISD) and that compound a set of abstract representations with the useful purpose of solving or addressing something that happens in their environment. Such pieces are obtained, or come, from Internal or External Agents who belong to different fields of the same domain, and they know about the problem, their environment and the actions that must be carried out in it, and they usually can be: specialists, decision makers, stakeholders, competition, workforce, clients, knowledge requirements engineers, cognitive engineers, cognitive architects...
- Information Systems (IS) is the information or data from a system<sup>4</sup> with access to selected data

clouds, databases or research sites about a given domain; and it is important to emphasize that:

- 1) the data, information or knowledge sources of the ahCN can be largely autonomous, geographically distributed and heterogeneous in terms of their operating environment, culture, social capital or goals, but they work in close collaboration to achieve the best common goals or, at least, compatible ones, and whose interactions could be internal, external or both to ensure proper functioning of the ahCN[3];
- 2) the Knowledge or Experience belonging to agents, from different fields, is capitalized in the Cognitive/Innovative Solution (CgI-S);
- 3) the Pieces of Internal Knowledge (IK) are considered as the foundation of the solution and the Pieces of External Knowledge (EK) are considered as the feedback the solution and influence, motivating the CgI-SAP team, to provide the best solution. It is important to note that some EK pieces come from neuroscience, biometric profiles..., often trivialized by Artificial Intelligence, but generate updated perceptions from the user's evolutionary experience, traditionally presented as insights.

### B. Cognitive Architecture

In this cognitive era, of surprising changes that have taken place in an extremely fast period, the idea of Cognitive Architecture must be properly delimited. Therefore, the authors consider convenient to achieve the homogenization of concepts or paradigms, related to the cognitive field and hypotheses about the nature of mind, among those who work in this area.

The task is hard because every day something new about cognitive arises, but it is worth trying to go in the same direction. Consequently, we agree with [4] when they point out that Cognitive Architectures are hypotheses about fixed structures, and their interactions, intelligent behavior underlying natural or artificial systems. In essence, a Cognitive Architecture must have a Semantic Base, derived from a Cognitive Analysis; which, in turn, is the essential component of the Cognitive System that must support a CgI-S.

**Semantic Base:** The semantic base formalizes, through a consensus, the relationships between concepts or terms and their attributes belonging to the domain related to CgI-S. The terms are registered constituting knowledge through an extended lexicon (KDEL) that classifies them into objects, subjects and verbs and is based on LEL[5]. This knowledge externalization allows the achievement of a consensus among the interested parties and consequently minimizes the symmetry of ignorance.

The concepts and relationships identified generate a matrix called Piece of Knowledge (PoK). It also facilitates the construction of a conceptual graphic

model that provides a visual medium for the semantic base of the domain and facilitate its validation, where an entity-relationship model can be used. Generally, after forming a semantic base, it is common to find that a good amount of terms used in the domain are ambiguous, are not unified and are particular to those who use them. It is important to bear in mind that, although the domain specialists validate the description of the concepts of the lexicon, the graphic conceptual model provides a very complete description of the knowledge of the domain that allows domain specialists to identify possible errors and what lack in the semantic base; particularly, between the relations of the concepts. This is very important, since this model is essential for the design of a Cognitive Architecture.

**Cognitive System:** Set of entities, definitions, rules or principles that interrelated orderly contribute to formalize a cognitive process, at least the irreducible set of components that allow to explain or carry it out.

### C. Knowledge Management on a Systematic process (KMoS-REload)

The Systematic Process for Knowledge Management KMoS-REload (Fig. 3, all details in [5]) is specially designed to interact with Informal Structure Domains (ISD), supporting the Cognitive Analysis, and provides a formal procedure for obtaining, structuring and establishing formal knowledge relationships that serves as a guide for the cognitive architect to: a) integrates the Cognitive Architecture that supports a Cognitive and Innovative Solution and avoid ambiguity, incompleteness and inappropriate links between pieces of knowledge in the context of a given Informally Structured Domain; and b) coordinate and operate the CgI-M model.

In particular the process performs three sequential phases:

- 1) Conceptual Modeling Phase which models the CgI-S's domain using a linguistic model and a graphic conceptual model;
- 2) Strategic Model to visualize the general functionality of the CgI-S's domain; and
- 3) Tactical knowledge phase, which is in charge of obtaining, discovering, giving structure and enrichment to the knowledge of the CgI-S.

In addition, cross-cutting activities are included to identify tacit knowledge, and once this knowledge is explicit, the wrong beliefs are recorded and the relationships between the concepts and their behaviors are traced.

Three activities complement the models used in the process:

1. the identification of tacit knowledge;
2. the capture and updating of specialized knowledge in the matrix; and
3. the false assumptions record.

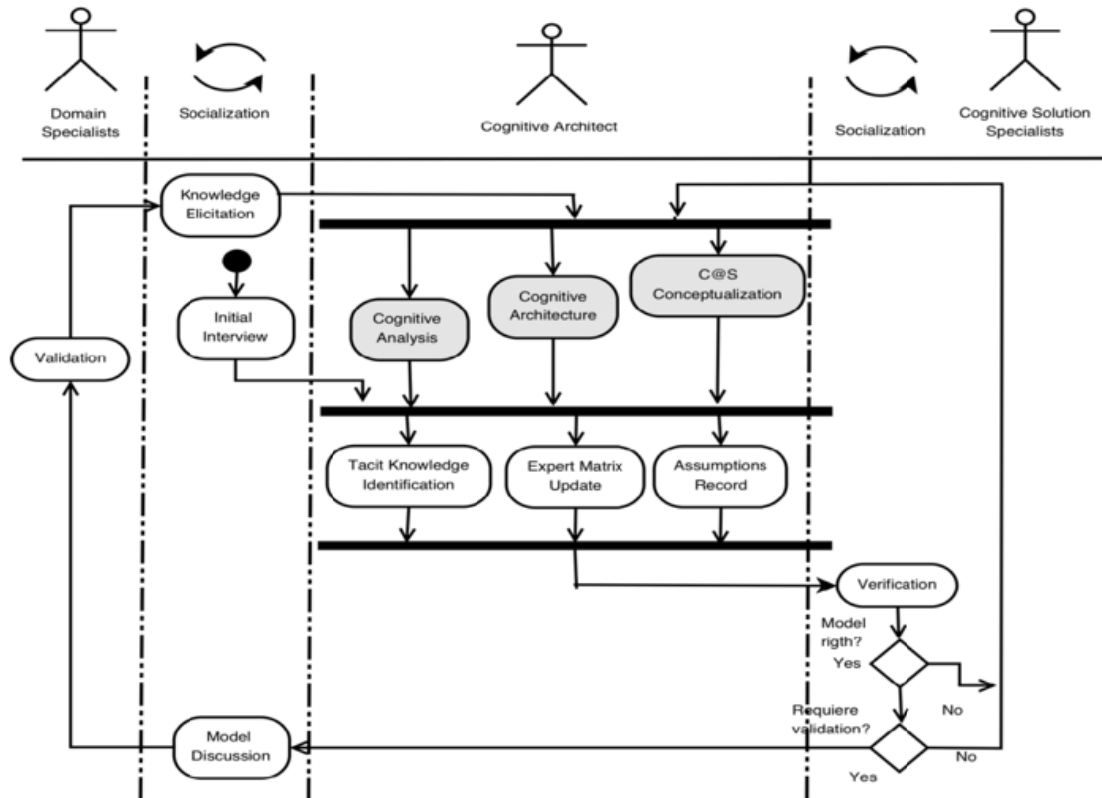


Figure 2. General overview of the KMoS-Reload process

The process begins with an initial interview between the Solution's Architects & Providers (CgI-SAP team) and the Internal or External Agents (Domain Specialists) in a session where socialization predominates. Then, the Tacit Knowledge Identification, the Expert Matrix Update and the Assumptions Record are developed in parallel by C.Ar (or the CgI-SAP team)—a Cognitive Analysis is done by them in a socialized way—in order to verify the artefacts and decide if they should continue with the following phases or require a validation of them. In fact, under a lean or agile innovation approach, exist living iterative processes that allow adding value from the validation of their elements and proposals. The validation requires that the CgI-SAP team explain the models to the Agents, who validate the knowledge. The process-in-turn generates more knowledge, then the cycle starts again, and the process may end when all those involved in the CgI-M Model obtain an agreement. Finally, the process makes the team aware that in order to develop a CgI-S is necessary to understand and formally define, the knowledge requirements and the domain that circumscribes them too [6]. The details of the KMoS-REload process application can be found in [7].

#### D. The cornerstone of the Cognitive/Innovative Solution

What is a solution? In the CgI-M model context, a solution means solving a situation, problem or need of an individual or company (the client), through the experience and talents of a highly specialized team of

people. Despite the fact that the concept of a solution is simple, the cornerstone of a Cognitive/Innovative Solution (CgI-S) is the result of processes, actions..., obtained collaboratively. Thus, CgI-S is the result, given by Solution Cognitive Architects & Providers (CgI-SAP team), of solving a problem or cognitive need taking into account the connections and relationships of the models obtained from Cognitive Analysis (CgAn), making use of the Internal Knowledge (IK) and External Knowledge (EK), and any other feedback from the Informal Structure Domain. Therefore, CgI-S can be represented as a function of three parameters that can be represented by (2).

$$\text{CgI-S} = F(\text{CgAn}, \text{IK}, \text{EK}) \quad (2)$$

Equation 2: The CgI-S is the result of the development and implementation function carried out by the CgI-SAP team.

At this moment, it would be convenient that two concepts are in mind: Open Innovation and Corporate Venturing. Today, companies are learning that their innovation models and proposals can find more value—and much faster—if they find a way to integrate the approach and proposals of their potential clients into their innovation models by the way, users of their technologies can usually express their needs more easily with respect to technology itself. Today, reorienting its research and development efforts, originally armored towards an open innovation

approach that includes the multiplied vision of its clients, adds much greater innovation potential and more varied. Companies such as Telefónica are leading worldwide collaboration initiatives such as these; the term that has been coined to name this type of effort is that of “Corporate Venturing”, where companies allocate resources to encourage startups or small businesses to develop new concepts indeed much more economically accessible.

Cognitive Innovative-Solution Architects & Providers (CgI-SAP) team: This is a team of human talent that performs consulting and analysis of information technology systems, intelligent and cognitive. The CgI-SAP team supports all its activities, within the CgI-M model, in a KMoS-Reload process to develop cognitive and therefore innovative solutions that bring great value to clients. It is well known how engineers or scientists become obsessed with past solutions and how the process of scientific discovery and the engineering design process can lead them to new solutions. However, there is still much to understand about the cognitive and innovative processes, particularly with respect to the natural cognitive processes that underlies it. Behind the KMoS-Reload process there are theories and methods of several disciplines related to cognition and knowledge such as cognitive psychology, social psychology, knowledge representation, machine learning... to analyze, structure and formalize the complex cognitive processes that occur in the real world, the world of the Informal Structure Domains. It implies that the CgI-SAP team is highly trained to be empathetic and solve problems of a given Informally Structured Domain. Consequently, there are two essential roles carried out by this team: as an architect of solutions, the team must have a balanced combination of technical, social and business skills; and as a supplier, the team must offer solutions based on any combination of technologies, processes, analysis, commercialization, internal organizational environment or consulting. Such solutions can be customized for your clients; or, it can provide solutions based on existing products or services.

Regardless of the roles played by the CgI-SAP team, the core of its activity is the interaction with the elements of the triplet of equation 2 and applying science and technology advances to take advantage of all the knowledge that exists around to achieve the Capitalization of Experience or Knowledge and to provide a CgI-S. It is undeniable that the above represents a complex situation [1], [2], but an excellent opportunity for the CgI-SAP team.

Cognitive Analysis (CgAn): The CgAn is a process of examining in detail a given ISD in order to understand it or explain it. Commonly one or several strategies or processes are used that allow to know and formalize the existing relationship between certain types of functions, actions and concepts related to this domain. The main objectives of performing the CgAn in a given ISD are: a) to obtain the best view of your own internal

processes, e.g., in a business domain could be how the market receives its products and services, customer preferences, how customer loyalty is generated or other key questions where precise answers are used to provide a company with a competitive advantage; and b) to set up the cognitive architecture established by the semantic base and the components of the appropriate cognitive system.

It is worth mentioning that often the CgAn focuses on the realization of a predictive analysis, where the extraction of data and other cognitive uses of the data can generate business and commercial predictions. Therefore, the practical problems surrounding such analyzes involve the precise methods used to collect and store data in a special location, as well as the tools used to interpret this data in various ways. Solution Cognitive Architects & Providers can provide analysis services and other useful help, but in the end, the practical use of the analysis depends on the people who are part of the domain, where they not only need to know how to collect data but also how to use it correctly.

### E. Agile Process of Innovation

The high dynamism and constant change of the world and its markets require that innovation is contained in an agile, continuous, cyclical and constant process of changes and adjustments where the CgI-S frees time from the process actors so that they focus on supervisory activities and that can agilely search for new products, services, internal processes or improvements, adaptations or updates to existing ones. Currently, a "Complete study of x-ray computed tomography magnetic resonance imaging" of the client's environment or its ISD is required to identify areas of opportunity and map the process, know the products and services to clarify and be assertive in the client's vision and goals. From the beginning of the KMoS-Reload that will implement the CgI-S, through the CgAn, this "Complete study" starts and the client will become aware of the intangible good that will be obtained. The Cognitive Architecture, since it is being formed, is offering the client content and tentative activities to be carried out.

Finally, the expertise of real solutions implementation indicates that innovation is implicitly presented-however marginally-and even more, it accelerates the cyclical process of innovation whose impact can occur as an improvement of Products, Services or Processes; or, the generation of new ones.

### III. FLUTEC: A CLIENT STUDY

FLUTEC worldwide company—located on the US-Mexican Border (Juarez City)—designs, builds, and sells Heating Ventilation and Air Conditioning (HVAC) modules tailored to meet particular needs of its clients; that is, each module could be similar but not identical. In fact, a build-to-suit approach for every project makes a high-cost project.

To find greater benefits from a project requires the improvement of the process to carry out it: The HVAC project process starts when a client issues the basic specifications for its design and ends with the delivery of it. Therefore, it includes a maremagnum of aspects to take into account when carrying out a project and, consequently, an erroneous decision making directly impacts the time of the general process and even its viability. In addition, the dynamism of the HVAC's singular market motivates the company to find greater benefits, and at the same time obliges it to continuously improve its processes, especially the delivery time of the project budget, the time and the quality of the design process...

Once the Flutec's environment relative to the HVAC's design process has been identified as an ISD domain, the Cognitive Architect starts the KMoS-REload process to characterize and, consequently, establish the CgI-M model in order to give an adequate cognitive solution (CgI-S), the CgI-SAP team identified the elements of the HVAC's process that needed to be improved and established a consistent model that would give it the corresponding support.

In summary, the establishment of an adequate cognitive architecture, using the KMoS-REload process, manages to capitalize the knowledge of the ahCN and its expertise, explicitly and formally, to allow: a clear understanding of the project's ISD; its assimilation by the CgI-SAP team; give a CgI-S; and characterize, as a whole, the CgI-M model—to a total customer satisfaction—whose remarkable products were a new DNA guide and the CBR prototype.

#### IV. DISCUSSION

In spite of some solution providers, the more complex the domain and the problem to be addressed, it is imperative to use a model. Solution providers are already faced with situations where they have developed simple CgI-S without starting from any model and, after a short time, notice that the domain grew in complexity nullifying the effectiveness of the solution to the detriment of the quality of its service and the loss of the client.

Finally, the CgI-M model after being used in real cases that its components as a whole can, de facto, respond through a cognitive collision to situations that occur within the domains of informal structure. There is a lot of work to be done on the subject of obtaining and representing common sense information; for existing frames of representation must evolve and be integrated with other frameworks in order to enhance representation and, consequently, reasoning with common sense information. In general, the results obtained by CgI-M suggest that the knowledge obtained from it is highly congruent with that expressed by ahCN when validated by the client and the results of the solutions provided by it.

However, it is also clear that it is not possible to explain the complete cognitive process of ahCN

exclusively in the current terms of the CgI-M model. Consequently, the model is open and dynamic for the improvement of its components and better explain the harmonization and integration of different types of cognitive processes that are supposed to coexist in a perspective of heterogeneous representation and for which additional research and collaboration among those we approach are needed. this type of topics.

In particular, in our opinion, such improvements should be oriented to: i) in which cases the components of the CgI-M model play a more relevant role in establishing the scaffolding necessary to develop a particular cognitive solution ii) or cases where they are not at all evoked by a cognitive system, since the need to react in real time is more urgent and, therefore, iii) accelerate the activities proposed by the model. Since there is no clear answer to such questioning, these aspects will imply, in our opinion and in congruence with [7], the future research agenda of cognitive psychology and the investigation of cognitive—artificial—systems.

#### CONCLUSIONS AND FUTURE CHALLENGES

This paper communicates the convenience of walking in the direction of an archetype that characterizes the essential aspects of Cognitive Architecture.

It was argued that, based on the results of client studies, these aspects should be addressed to formalize and accelerate the establishment of Cognitive Architecture with the limitations and challenges that require the daily tasks of a cognitive process.

Finally, there are already several crucial problems of real situations have been addressed by our model of which one of them was mentioned where the cognitive processes are harmonized in the CgI-M, interacting with an ahCN, and reflected in a cognitive architecture that supports to the CgI-S implemented by the Cg.Ar. The results obtained suggest that, although the systematic process for knowledge management KMoS-REload provided by the CgI-M represents an adequate way to integrate different knowledge acquisition and representation mechanisms, it is still not clear if they are sufficient and robust. Therefore, it is still an open question what and what kind of processes, techniques or elements should be part of a general architectural mechanism and if it is worth implementing them in the processes of the model to operate their conceptual structures. As mentioned above, answers to questions or efforts will require a joint research effort on the part of cognitive psychology and the community of cognitive models and processes, cognitive computation, machine learning and artificial intelligence.

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