Knowledge Management on a Strategy for Requirements Engineering (KMoS-RE) and Case-Based Reasoning (CBR) Applied in Cooling Unit Design

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ABSTRACT
Every day it can be observed that there are situations that are resolved based on each person experience, which is obtained by solving situations that happened before whether the solutions were correct o incorrect. Therefore, the CBR is widely used for solving problems that are distinguished by the need to use the experience gained previously. On the other hand, there are situations where you need to have well defined what you want to do or what it is asked to be made, for that, the KMoS-RE strategy helps to define the requirements. In the productive sector, having specific requirements and the experts experience is very useful for the projects to be designed, developed and delivered as they were requested.

Keywords
Case-Based Reasoning; CBR; KMoS-RE

1. INTRODUCTION
Nowadays to provide a good quality service or produce a product, it is necessary to know the needs and characteristics of the problem that is intended to be solved; those features only the person or people who know the needs can express them. Although this does not assure that the needs are the ones to be solved; since often the final user has the tacit knowledge and is difficult to explain what he needs. The KMoS-RE strategy is focused on making the transformation of tacit knowledge to explicit knowledge through a series of activities that helps the requirements engineer obtain the expert knowledge or the user who has the need. In addition, the Case-Based Reasoning is a tool that simulates the way humans solve problems, because usually a human being builds on its experience how to solve new problems that have similarities with the previous problems.

In this article KMoS-RE methodology and CBR are combined to give a solution to the needs of the company Flutec, which is related to the design and manufacture of cooling units; resulting in a customer satisfaction when results a shown.

2. BACKGROUND
The Cased-Based Reasoning (CBR) focuses in the problem resolution, having a baseline the previous solved problems and the solution to these problems. In this type of resolution it is very similar as the way humans resolved the day to day problems, whether is it conscious or unconscious humans always remember the similar situations before making a decision or giving a solution to the problem. [1]

Bear in mind, it can be said that the case-based reasoning (RBC) it is a problem solver oriented paradigm, which needs a previous knowledge of the domain that is known as experience and relying with the previous solutions of the problems, doing the necessary comparisons so that gets to the optimal solution for the problem.

The CBR has a cycle that follows in order to give a solution to a new problem in the domain we are dealing, it is divided in four parts, which are: retrieve, reuse, revise and retain. In order to begin the CBR cycle, it is needed a case base, which means that is essentially to have represented the previous problems set. To do this, it is said that the problem is represented in a case. Generally, in the figure 1 it can be observed the RBC cycle.

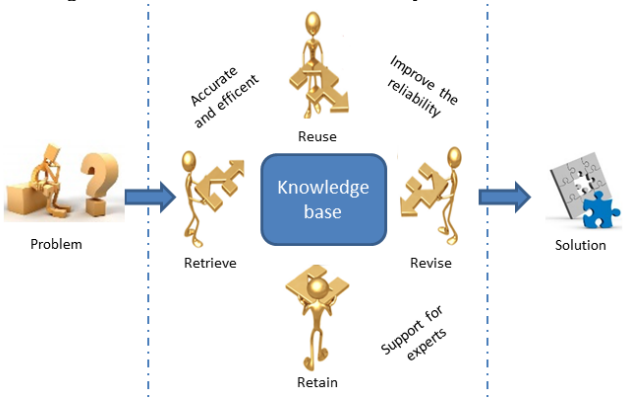

Figure 1: Case Based Reasoning cycle [2]

With the use of Case Base Reasoning it is pretend to model the knowledge that the experts had in the domain that is going to be applied in the CBR.To do so, it is necessary to implement together with the CBR another tool that help us obtain the knowledge of the experts, on certain occasions the language used by the experts it is not understood at all by the requirements engineers and this can lead into suppositions or assumptions things that don't belong in the domain. Actually, there are already tested tools for obtained an experts knowledge an one of them is the Knowledge Management on a Strategy for Requirements Engineering (KMoS-RE) [3][4] is it a strategy design for create, structured and obtain knowledge in domains ill-structured, than can be in incorporated to a problems solution and avoid incomplete and ambiguous requirements. In the figure 2 shows the general way that KMoS-RE consists. Later it is detailed each of the artefacts that conforms a part in the strategy.

KMoS-RE strategy consist of:

- Record of beliefs: In this point, annotations of assumptions are taken by the requirement engineers that they have about the domain in which they are working, with the purpose that if a new member is added to the work team, the new member does not formulate the

same assumptions and his integration is easier to the domain.

- Knowledge of Domain on an Extended Lexical (KDEL): To generate this artifact, interviews are made to the experts, then analyze the info, which means the requirement engineers listens it, generate notes and then ask questions to the experts in the domain. With that being said, the requirement engineers are capable to obtain concepts, definitions and relations used in the domiain so that they can elaborate the conceptual model.

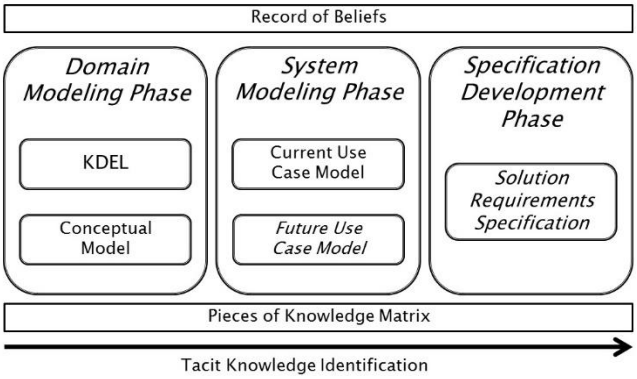

Figure 2: KMoS-RE strategy. [3]

- Conceptual Model: Is generated based on the KDEL, which is showed to the domain expert and he validates the information contained in the model. In case there is some inconformity, it is notified to the requirement engineer and he does the modification.
- Current use case model: Contains the functions of the current system, which means, the way the things are done actually. To get an idea on how it is conformed and the used of each terms that are in the KDEL.
- Future use case model: This is the actual system enhanced, these adds o eliminates functions to the current system.
- Specification document: Contains all the required information to develop the system that the expert is requesting

There is a domain ill-structured belonging to Flutec Design + Build Heating Ventilation and Air Conditioning (HVAC), Flutec is a company that offers their services in an international level, their mainly activity is the design and custom made production of chillers, Chil-Paks, vapor and air compressed modules. All of the mentioned is offered to a company level.

Off all the product types that Flutec elaborates, the boarded projects are the ones relative to the cooling units (chil-paks). In used terms of the domain, a cooling unit is a central plant integrated, packed in a plug and play unit. To develop each cooling unit, the engineering department must meet a set of characteristics or features that are considered unrepeatable and unique, because it relies heavily in the use they give to the cooling unit, for this reason it is ideal that these characteristics or features are granted by the person responsible by the client, in the majority of cases it is a mechanical engineer the person responsible. Taking all this into consideration, to develop a proposal must be done independently, considering that the amount of information is huge; in the same way it must be contemplate the knowledge gain by the experience of the team work working in the project.

Actually Flutec uses a document that is called DNA, this is their support tool for obtaining a better definition of the chil-pak that a client requires and with this ensure that the propose given to the client meets with the expectations. One thing must be remembering in order to develop any type project, if the specification or the characteristics are not well defined, ambiguous or it is not well understood what the client is needing, the final product will be something different of what the client is requesting. Once the DNA is ready it is considered an empiric requirement document and it is taken like a base for the design and construction for the chil-pak.

Flutec currently uses a document that is called DNA, this is their tool support for better definition of the cooling unit that the customer needs and thereby to ensure that the proposal will be given to the customer meets the same expectations. It is worth remembering that in order to develop any project, whether the specification or the features are not well defined, no ambiguities or misunderstanding of what the customer is asking, the final product will be something different than what the client is requesting. Once the DNA is ready it is considered as an empirical document of requirements and is taken as a basis for the design and construction of cooling units.

To Flutec is of utmost importance to define in detail the cooling unit that the client has in mind, as Flutec staff invest time and resources for the generation of proposals that are sent to the client for assessment, this is done in order to obtain the development of the cooling unit. Therefore, the problem that arises in Flutec is when they generate the proposal, because the DNA is currently filled by several people within the company, and sometimes require the intervention of the engineering department. By requiring a long time to develop and submit a proposal, It is in this step where it causes a great disadvantage to Flutec against their competitors market. In addition to elaboration time, other factors affect the delivery of the proposal as it is, the knowledge is distributed among experts of the company, this factor affected when one of the experts is absent and there is no one who can replace it at that time. Another factor is teamwork, as there is a very strong dependence on the engineering department and this depends on many characteristics of the cooling unit.

Performing a domain analysis and the information handled in Flutec, it was founded that Flutec made custom made water cooling units (chil-pak), which means that a chil-pak is generated based on the specific needs for each client. Therefore, Flutec staff and sellers use the document called DNA to collect customer information and make this a proposal to the chil-pak containing the specification given by the client. The higher definition it has of what the customer requires, better product will be delivered and the lower the probability that the product delivered has any errors, with this Flutec meets customer needs.

At present, although the DNA was conceived as a document to assist in the definition of the cooling unit, this document is of little use because of its complexity filling. In addition, people who interact with DNA at the beginning of the project definition unknow the meaning and use of information that is required in the

DNA, leaving the document incomplete and forcing the interaction with others in order to finish the DNA filling. This is reflected in time consumption and results in missing opportunities that Flutec may keep with the development of the cooling unit.

Studying the information provided by the company through KMoS-RE strategy and knowing the characteristics for using the case based reasoning, it was chosen to represent knowledge using the pair attribute - value, and use the CBR to give a solution to the need of the company.

3. DEVELOPMENT PROCESS

It started with an interview to become familiar with the domain in which it will work. After that, a model of the domain was done and it was validated by engineering coordination, since they are the ones who generate proposals. Then it was performed a series of interviews with the general director and the engineering coordination in order to complement the domain model that had been done.

It was observed that for handling a DNA there are different approaches over its importance. On one hand, it is believed that if you do not have a DNA it could not get a good definition of the cooling unit desired by the customer and that the proposal submitted may contain ambiguities that affected at the time the proposal is authorized; seeing the other point of view that they have of the DNA within Flutec , it is consider very tedious filling and also is not much help for the project, as they only take a few data from the DNA for the preparation of the proposal and the construction of the cooling unit. Therefore, as they cannot see a use of the DNA, they left it out or simply filled when the proposal was generated.

The way to apply the KMoS-RE strategy consisted in recording the interviews made with the general director and engineering coordination of Flutec were made, subsequently the interviews were transcribed and then it began to work with the domain modeling phase of the corresponding in the strategy KMoS-RE. In this first phase, the extended lexicon of language (KDEL) was made, in other words, terms, symbols, concepts and relationships of the domain were obtained. Subsequently, the conceptual model was elaborated and validated by the engineering coordination was conducted. Realizing the first phase of the strategy, helped us to know the domain and to better understand the terms used by the domain experts, because when the project started the cooling units was a domain completely unknown.

The information gained in the interviews is:

- The explanation of Flutec's business activity.
- The DNA importance for the definition of a water cooling unit.
- The use of the DNA for the proposal generation.
- The working process in FLutec for developing a chil-pak.
- Flutec's organization.
- The meaning of each phase used in the DNA.
- The basic information for generate a proposal or a chil-pak.

The information contributed by Flutec is:

- Access to the DNA's registered in their actual system.
- Filling DNA information belonging to a project.
- Visualization of a PIN ID and MH100 plan.
- Organization of the physical information of a project.
- Phases in which the DNA's is organized.

When the information it was already had, an analysis was done, in which case it realizes that a DNA besides being used for defining the chil-pak, also is used to track the project, which means, is used to know the stage that the project it is. The aim is to know what projects are in current guaranteed.

Taking the basic information for generating a proposal, it was chosen to use the CBR to give a solution to the need of the company. That led to implement the RBC in the company. Since basically the Flutec Company requires decreasing the time that takes to generate a proposal and this ranges from the time the specifications are sent, through filling DNA and arriving in the first instance to the proposal that is sent to the client approval. That led to undertake the development of case-based reasoning to solve the need that the company has Flutec, the way it was working was:

- Having the domain model that was obtained from the KMoS-RE strategy implementation, the most important attributes for the engineering coordination were obtained, in example, the most significant data were taken from the approach of engineering coordination that they were useful to them in order to compare or select previous projects.
- After that it was continued by assigning them the importance to the attributes, with the purpose to detect the attribute that has the highest priority for developing the proposal of a chil-pak.
- Because the Case-Based Reasoning requires a case base to begin with its cycle, it was necessary for the case representation with the attribute-value combination; so that these cases were introduced into the case base.
- Starting the Case-Based Reasoning cycle, for the recovery case phase, the formula of nearest neighbor similarity was implemented using the priority that was assigned to each attribute marked in the representation cases.
- By getting the most similar cases to the new problem, experts consulted to inform if the result was correct.
- Lately, the adaptation of the case was made and the domain experts decided if the solution given by the CBR is included or not in the case base.

Presenting the implementation of the CBR to the coordination engineering, it was realized that this implementation met the expectations that the company had regarding the project of Case Based Reasoning, since it was easier for them to detect if previously has already been made a project similar to the requirements of the new project requirements; with the purpose to obtain the plans and specifications of the equipment used in the solution of the mentioned project, thereby develop in less time the proposal so that it can be sent to the client.

4. RESULTS

At the moment of implementing the KMoS-RE strategy to structure their knowledge experts in Flutec, it was obtained the extended lexicon of language (KDEL), the conceptual model and the domain model. Latter on it has two views, one from the coordination engineering (Figure 3) and the other from the general direction (Figure 4).

An important part of implementing the strategy, is that people outside the domain acquired a basic knowledge of the domain more quickly, helping that the communication with the experts were smoother. Similarly, it can focus on the problem area, which means, it helps requirements engineers to delimit their questions or to address specific concerns of the domain, thereby transform as much tacit knowledge of the expert into explicit knowledge.

After carrying out activities from KMOS-RE strategy, the Case-Based Reasoning was implemented as a solution to the need of Flutec; The Service of Quality (SERVQUAL) questionnaire was applied to the persons involved in the project to meet the expectation and perception of the company to the service that was given. Within this questionnaire the questions are classified into 5 categories: tangible, reliability, response, warranty and empathy. The minimum score that can be obtained in response to each question is a number 1, which means that the respondent completely disagreed with was is stated in the question; the highest score you can get is a number 7 which represents the respondent completely agrees with what is stated in the question.

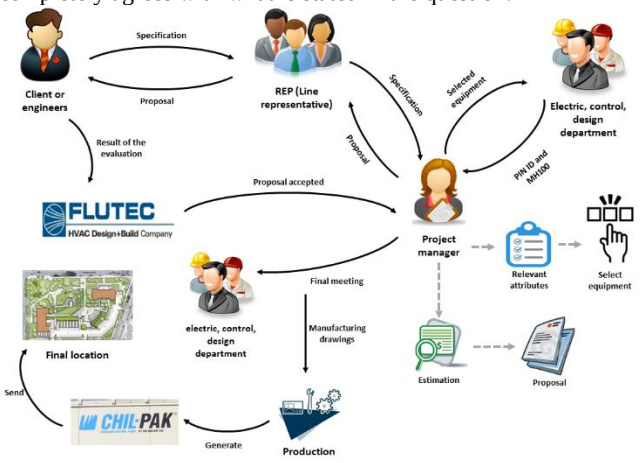

Figure:3 The domain model from the view point of engineering coordination.

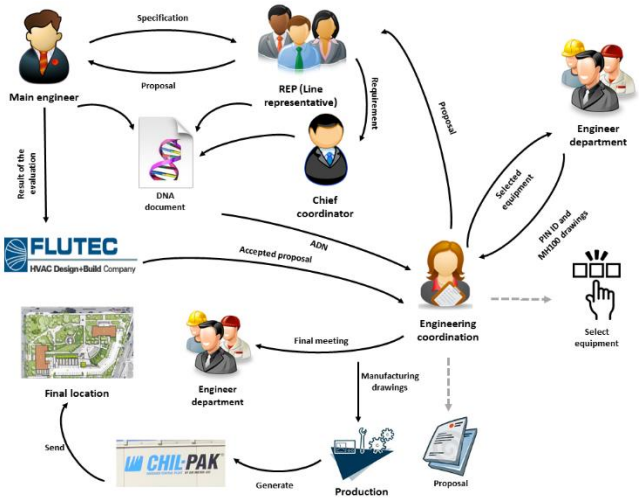

Figure:4 The domain model from the view point of general director.

The result gained from the questionnaire applied is that the service provided met 107.97 % the expectations that Flutec had in mind, which means, the service surpassed the expectations of the company. This can be seen in table 1.

Table 1 *SERVQUAL* Questionnaire application results.

Category	Average expectation	Average perception
Tangible	**1.00**	**4.33**
Reliability	**6.20**	**6.20**
Response	**6.75**	**6.50**
Warranty	**7.00**	**6.75**
Empathy	**7.00**	**6.40**

On the other hand, the Software Usability Measurement Inventory (SUMI) questionnaire was also applied in order to measure the expectation and perception of experts Flutec as the prototype was delivered. For this questionnaire the questions were classified into 6 categories: accuracy, usability, documentation and visibility, understandability, reliability and efficiency. In the same way that the SERVQUAL questionnaire application, the minimum score to answer a question is the number 1 and the maximum score is number 7 , where the number 1 represents that the respondent is completely disagree and the number 7 represents the respondent is completely agree.

After performing the application of the questionnaire and analyze the results it is concluded that the prototype of CBR fulfilled with 88.65 % of customer expectations; this data is obtained by considering the data shown in Table 2.

Table 2 SUMI questionnaire results

Category	Average expectation	Average perception
Accuracy	6.43	5.14
Usability	6.67	6.13
Visibility and documentation	6.80	6.00
Understandability	6.90	6.40
Reliability	7.00	6.00
Efficiency	7.00	6.50

5. CONCLUSION

After carry out the implementation of the KMOS -RE strategy and the Case-Based Reasoning (CBR), it was concluded that not only in software development the requirements are used and that these requirements need to be well defined to avoid ambiguity and errors in the construction of software or any final product. All off this in order that the final user is satisfied with the delivered product. In the vast majority of projects the definition of requirements it is not given the proper importance and therefore, the last thing you want is to spend time detailing the requirements because the customer needs is the product as soon as possible.

Unfortunately, when the physical development of the product gets more importance than the requirements, many things will be

assumed and in the future these suppositions can cause re-work, spend more time and that the final user is not satisfied with the delivered product.

For a company such as Flutec it represents a great disadvantage the fact that they depend on knowledge of its experts, and that they do not know at what point these experts will stop working for the company and carried them all the tacit knowledge acquired. Therefore, implementing strategies such as KMoS-RE for tacit knowledge of experts and the paradigm for Case-Based Reasoning helps this disadvantage diminishes greatly.

Speaking of Case-Based Reasoning for solving the need for the Flutec's company, it was observed that they perform the same CBR cycle unconsciously, relying on memory, knowledge and experience of its experts in manufacturing cooling units. Because the results obtained by the CBR corresponded with the results obtained by performing experts latter cycle empirically.

6. FUTURE WORK

Since two points of view are shown to generate a proposal and a water cooling unit, it would be interesting to carry out an experiment in which both the General Director and the engineer coordination work on a project each in their own way, to determine if they come to the same solution and evaluate which option was the best, in other words, evaluate execution time and evidence generated in each of the options.

Additionally, it was observed that there is a strong dependence on the engineering coordinator which leads us to recommend that a transitional simulation must be done, so that the person currently in charge of projects trains new member that stays in that position. When we have important members in a company, it must have contemplated the benefits and disadvantages that brings, because that depends on the economic stability of the company.

If another use was given to the DNA and the information contain was reformulated, they could be forced to use it. Because it is always important to have a good requirements specification before develop or construct any product. Most of the time requires considerable time to achieve a good specification, but this will bring benefits as reduction of construction time for the company this can translates into money as it can acquire more projects. It can be seen it from the customer's perspective, which will be satisfied with the product delivered and it will meet the needs expressed.

Other uses that the DNA could have are:

- A checklist, which means after the complete construction of the cooling unit it could be used to verify that all the specifications given by the client are in the cooling unit.
- Use the DNA information for statistical production.
- A Tool that helps to track the project progress, which means, if a proposal or project is consulted the information contained was up to date.

In addition, if all the projects information is available this would be used as a base for developing future proposals and projects. With this, the process of generating proposal does not depend on the knowledge of one person.

7. REFERENCES

[1]. A. Aamodt, E. Plaza(1994) "Case-Based Reasoning: Foundational Issues, Methodological Variations, and System Approaches". AI Comminications. IOS Press, Vol. 7: 1, pp. 39-59.

[2]. A. Fornells (2009) "A Unified Framework for the Development of Case-Based Reasoning Systems". Recuperado el 23 de Marzo de 2016, de http://lasallerd.salleurl.edu/A_Unified_Framework_for_the_ Develop-ment_of_Case-Based_Reasoning_Systems%2C

[3]. Olmos-Sánchez Karla… [et all]. (2015) "Requirements engineering based on knowledge: a comparative case study of the KMoS-RE strategy and the DMS process". Revista Facultad de Ingeniería, Universidad de Antioquia, No. 77, pp. 88-94, 2015.

[4]. K. Olmos and J. Rodas. KMoS-RE: knowledge management on a strategy to requirements engineering. Requirement Engineering Journal. 2014. ISSN 0947-3602, Volume = 19, Number = 4, Springer-Verlag New York, Inc.

[5]. M. Behbahani, A. Saghaee, R. Noorossana (2012) "A case-based reasoning system development for statistical process control: Case representation and retrieval". Computer & industrial Engineering, Elsevier. Vol. 63 pp. 1107-1117

[6]. H. Li, J. Sun (2009) "Predicting business failure using multiple case.based reasoning combined with support vector machine". ELSEVIER Expert Systems with Applications Vol. 36 pp. 10085-10096

[7]. S. Ji, M. Park, H. Lee (2012) "Case Adaptation Method of Case- based Reasoning for Construction Cost Estimation in Korea". Journal of Construction Engineering and Management ©ASCE Vol. 138 No. 1 pp. 43-52