

# Managing Knowledge about Resources for Autonomic Computing

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***Abstract.** Nowadays, in the IT scenario, there is an increasing need for knowledge to solve problems in a faster and safer way. People create and change information faster than in the past. Although the majority these exchanges are made via the documental form, there is also a large amount informal or tacit knowledge exchange in people's interactions. The GCR environment was designed to aim at the use of Knowledge Management in the Autonomic Computing scenario. There, employees can be provided with all necessary knowledge to execute their tasks, to make decisions, collaborate with one another, disseminate individual knowledge to transform it into organizational knowledge, and organize and create knowledge about symptoms and problem resolutions. This article shows the GCR framework and its current status.*

*Keywords: knowledge management, organizational knowledge, knowledge creation, autonomic computing.*

## 1. Introduction

Nowadays employees and IT managers create and exchange information quicker and in much greater volumes than in the past. Even though a large part of this interchange take place via the documental form, like technical reports, articles, magazines and books, there is also a great deal of informal or tacit knowledge interchanged between people.

Knowledge Management (KM) emerged to administer knowledge and its continuous development. Its goal is to create means so that an institution responds dynamically and efficiently to the environment. For this, it should arm people with all the possible knowledge to enable them to execute their tasks, help in decision-making, provide ways of collaboration and disseminate individual knowledge enabling it to be part of the organizational knowledge.

As Autonomic Computing (AC) is an area of intensive knowledge creation, which needs to be managed, in this work we analyze the possible contributions of KM for AC, proposing an environment to help knowledge management of human and autonomic elements.

The remainder of this paper is organized as follows: Section 2 discusses a number of theoretical Knowledge Management and Autonomic Computing aspects and section 3 explains our proposal. Future works and the conclusion are shown in section 4.

## 2. Knowledge Management and Autonomic Computing

Knowledge Management is a new branch of management for achieving breakthrough business performance through the synergy of people, processes, and technology. In brief, Knowledge Management is the process through which organizations generate value from their intellectual and knowledge-based assets, also generating value from such assets the involves coding what employees, partners and customers know, disseminating this knowledge and sharing it in an effort to get competitive advantage.

According to Polany (1983), there are 2 kinds of knowledge: explicit and tacit knowledge. The first concept is also known as coded or formal knowledge, which can be articulated through language and transmitted to individuals; the last (also informal knowledge) means personal knowledge rooted on individual experiences and involving personal beliefs, perspective and values. According to the Theory of Knowledge Creation proposed by Nonaka and Takeuchi (Nonaka et al, 1995), knowledge creation occurs in four stages that represent the interaction between tacit and explicit knowledge, from the individual up to the organizational level, as shown in Fig. 1. This process of knowledge creation is dynamic, infinite, iterative, and occurs in a spiral.

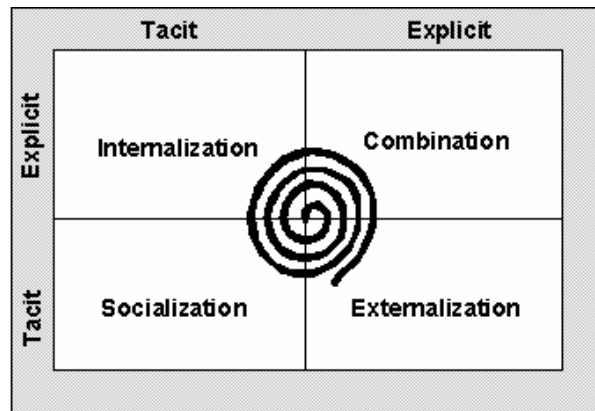


Fig. 1 - Knowledge Creation Spiral (Nonaka et al, 1995)

In (Stollenwerk, 2001), the author analyzed the main KM and strategic planning models, creating a generic model for this activity. For the composition of this model, seven processes were considered, which are:

- Identification – where the critical competences for the success of the organization (essential competences) are identified.
- Capture – It is the acquisition of knowledge, skills and expertise needed to create and to maintain the essential competences.
- Selection and Validation – This process is responsible for passing the knowledge through a filter, evaluating its quality and customizing it for future applications.

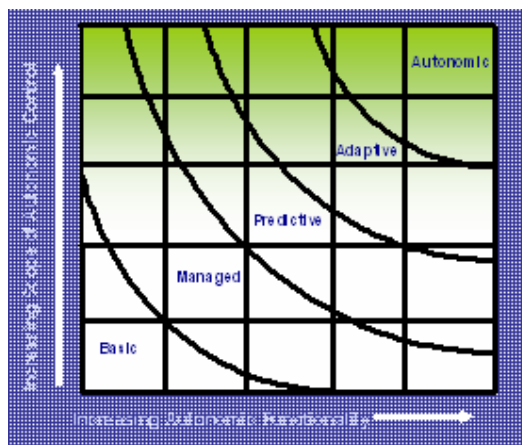
- Organization and Storage – Responsible for ensuring a fast, easy and correct access to knowledge.
- Dissemination – Responsible for the flow of knowledge in the organization.
- Application – Although knowledge, expertise and information are available and shareable, it is fundamental that they can be used in actual situations in the organization, producing tangible benefits such as performance improvements, new products and new clients.
- Creation – Responsible for the creation of new knowledge.

There are other issues which facilitate Knowledge Management, such as leadership, organizational culture, evaluation and IT.

In Autonomic Computing (AC), when we look for self-configuring, self-optimizing, self-healing and self-protecting solutions, first of all we are looking for knowledge-intensive solutions. It means: solutions which can manage its knowledge, disseminate it to other elements from its environment, and consequently, manage themselves. So, this work is based on Knowledge Management principles, which have been used with considerable successful in business and the attempt at transporting KM benefits to the AC scenario. Briefly, we try to translate how people manage their knowledge and disseminate it in an AC paradigm.

According to IBM (2005), there are 5 levels of Autonomic Maturity, as in Fig. 2, which are:

- Basic – Manual analysis and problem solving;
- Managed – Centralized tools, manual actions;
- Predictive – Cross-resource correlations and guidance;
- Adaptive – System monitors, correlates and takes action;
- Autonomic – Dynamic business policy-based management.



**Fig. 2 - Levels of Autonomic Maturity**

The higher the scopes of autonomic control and of autonomic functionality are, the more intense knowledge creation is (with autonomic elements or humans passing

through the internalization, externalization, socialization and combination phases) and the necessity for managing knowledge becomes essential. For that, we propose in this work an environment aimed at Knowledge Management applied to Autonomic Computing, which will be described in next section.

### 3. GCR: Our Approach

An environment was envisioned to provide some tools aimed at the Managed and Predictive levels of Autonomic Computing (Fig. 2) that provides resources to higher levels to manage and deal with autonomic elements. This environment is entitled GCR, the acronym for “Gestão de Conhecimento de Recursos” (Resources Knowledge Management).

#### 3.1 The Architecture

The GCR architecture, as shown in Fig. 3, is detailed in the following sections.

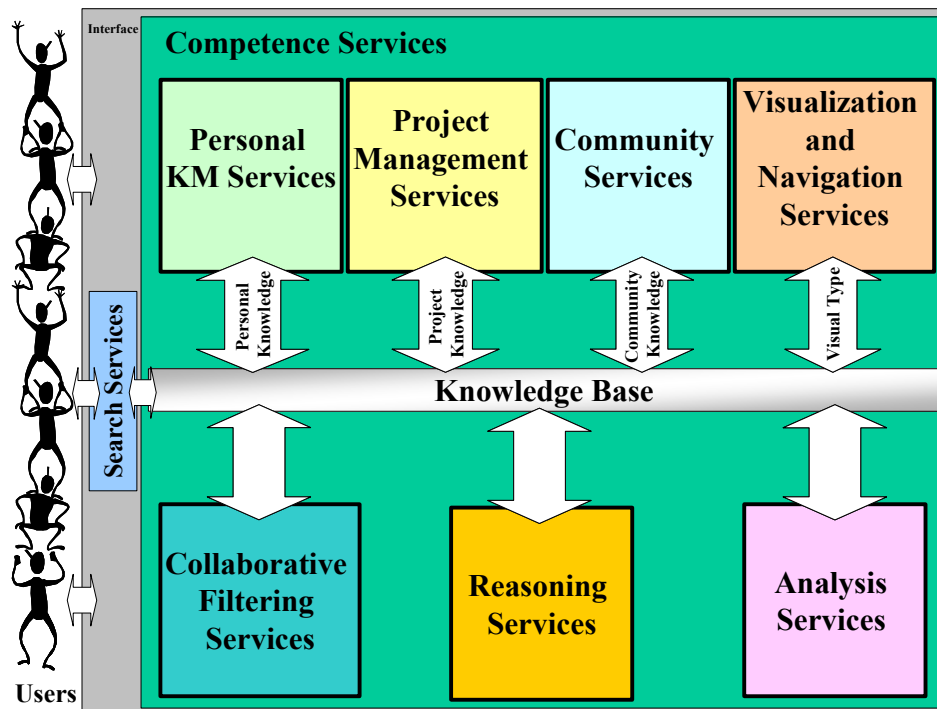


Fig. 3. GCR Architecture

##### 3.1.1 Personal KM Services

This module is responsible for providing functions for an employee (as a technician) to manage his/her personal knowledge, as well as information about him/her. So, these tools can help an employee to register ideas and solution attempts, personal information, organizing of ideas and so on. This module provides services such as:

- **Curriculum Vitae** – The curriculum vitae is one way of keeping information on a person. This information comprises the name, personal information such as address, e-mail, home page and phone number, academic background, professional activities, language skills, scientific production (if it exists), advisory data (if it exists) and prices.

In addition to this information, the user should state what his/her competences are, as well as his/her degrees of expertise.

- **Personal Blog** – it acts as a tool to provide personal knowledge management and reflects some topics from the user's profile. In GCR, by combining the output of several chosen blogs, one can obtain a tailor-made publication and contact people with the same interests. Moreover, the evolution of employee's interest and involvement about a topic is registered, as a chronological record of his/her thoughts, knowledge, references and other notes that could otherwise be lost or become scattered. So, this kind of information can be used as input to measure the competence of an employee and consequently help in choosing a more qualified professional to solve a problem in an autonomic element (when it could not solve it by itself).

- **Mental Maps** - In GCR, the user can construct mental maps to define concepts, help in brainstorm sessions and graphically simplify the job of discussion. Users can display some concepts as public, so that anyone can see them, their relationship with other public concepts, as well as their definition.

### 3.1.2 Project Management Services

This module is responsible for providing services to: i) control and manage one or more projects, ii) define and execute processes with a workflow tool, iii) store knowledge created during project execution, and iv) allow knowledge reuse. A project can be understood as an installation and configuration project, a study of new technologies, a support implementation process and others. This module has as functions:

- **Project Control and Management** – Here, the project manager defines schedules, goals, participants, the necessary competences (pre-requirements of the project and their levels), and some reports for resources (people, money and tools) control.

- **Process Definition and Execution** – The project manager or responsible employee creates the process model, with sequencing and restrictions for the activities, and the execution needs for each activity: needed competences for execution, value of these competences, inputs, outputs, and tools. Project-model creation is defined in a workflow graphic mode, and process execution control is done by a workflow engine.

- **Knowledge Storage during the Project** – During activity execution, the involved parties can add all kinds of explicit knowledge to this activity, such as reports, documents, manuals, comments, suggestions, best and worst practices, mistakes and ideas. Then all steps in the activity execution can be documented, and in the future we can track all kinds of created knowledge and the context in which it happens, an important factor for an inexperienced employee to learn about the process in a domain. The process model itself is a kind of knowledge which should be stored for further access. Contributions and publications are another kind of knowledge which people can disseminate during a project.

- **Knowledge Reuse** – All kinds of knowledge created and stored during a project, such as previous process-models and the knowledge described in their instance activities can be reused in full or in part by other users.

### 3.1.3 Community Services

One of the main foci in GCR is virtual-community creation, created by groups of people with a common interest (as a specific problem of configuration of a resource, as an example), who could exchange information and work together. This module displays a number of tools to improve the interaction between people in a community, such as surveys, forums, news, scheduled e-meetings, public library and events. Also, all conversations in an e-meeting are stored and categorized in one or more Knowledge Areas. A conversation can be interpreted as a kind of explicit knowledge. Storing and categorizing this knowledge can be useful for future consultations.

### 3.1.4 Knowledge Visualization and Navigation Services

It is made by:

- **Hyperbolic Tree** – In GCR, as shown in Fig. 4, the hyperbolic tree is used to visualize the Resource Ontology. The user can navigate through this ontology and through all information related to a knowledge area, such as projects (in green), competences (in yellow), people (in blue), communities (in orange), and symptoms.

This ontology is based on [Perazolo, 2006].

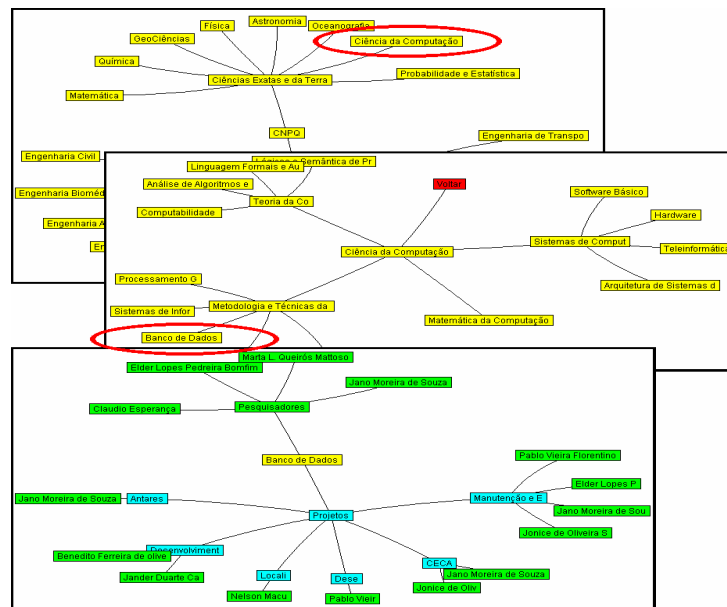


Fig. 4. Navigation in Hyperbolic Tree

- **Conceptual Project Map** – permits a tree-like visualization of a specific project. Thus the user can see all related information of a project, such as materials, contributions, participants, collaborators, managers, knowledge areas, and competences which are pre-requisites, as well as the workflow model. This map allows searching over it, and opening a matching node.

### 3.1.5 Competence Services

Currently, the main problem in an organization is the inability to discover what it knows, what its abilities are, what its employees and experts know, and in which

knowledge areas they work. In an AC context, discovering what an autonomic element knows about itself, and the environment and measure of this knowledge is very useful for managing AE usability.

### 3.1.5.1 Competences of a Person

A way of reasoning the competences of a person is by analyzing the documents that this person creates, edits and manipulates, and the frequency of these operations. These documents can be texts (as publications or notes), mental maps, project definitions, e-mails, blogs, and others. The services provided are:

- **SMiner** – Fundamentally, the SMiner [Rodrigues, 2004] function is to mine competencies based on texts/publications. In our approach, we use the Stemming technique to measure the relevance of a term by removing suffixes in an automatic operation. Terms are related to a person's competence, and these competences and the expertise degree (using the measure of relevance of a term) are stored in the database. Finally, after mining is done, it is possible to check the mapped abilities in a report provided by the application.

- **Competence Searcher** - Moreover, as important as identifying competences is searching for them and inferring the most similar competences when we do not find them. Thus, in our approach, the competences are searched following this order of priority, as per [Oliveira, 2005]: i) Declared competences – the competences that the person thinks she/he has. These abilities are recorded by the person herself and saved; ii) Project competences – correspond to the competences found in the employees' developed projects. We assume that if a person has worked in a project and executed an activity which requires some competence to be executed, then this person has this competence; iii) Extracted competences – recovered from published text mining by Sminer, described in the previous section; iv) Community competences – collected from the communities in which the user participates or contributes. It means that issues discussed in communities can be understood by their members. With these parameters, we can also measure the expertise of a person in a specific issue and rank people who have it. The result of this search is an ordered list with these criteria.

- **Weakness and Strengths** - In this work, we use the mapped competences of an institution to measure its weaknesses and strengths. Knowing weak and strong points, that is, knowledge areas where the institution has a good degree of representation and competences that should be developed further, respectively, the institution can be better positioned, developing planning and strategies to carry on, or to improve its current position, enabling continuous knowledge dissemination, and increasing internal interaction and collaboration, as per [Oliveira, 2005].

- **Recommending People for a Project and Community Recommendation** - The results of the competence search can be used as a support tool in decision-making when project managers are choosing employees. Also, having identified employee competence our approach does the following, as per [Oliveira, 2005]: i) if there are no communities about a topic, the environment searches for a number of people with similar interests and proposes new community creation or ii) suggests existing communities that match the profile of the future member. Depending on the topic, a person can belong to more than one community.

### 3.1.5.2 Competences of a Autonomic Element

Some metrics are used to identify and measure the knowledge of an AE. These metrics are:

- **Accuracy** – The degree of accuracy of an AE on the identification of symptoms and prediction of incidents and problems. If an AE is able to successfully identify a set of symptoms, we can deduce that this AE knows about these symptoms. So, the more an AE can identify some problems or incidents, the higher its knowledge about these symptoms is.
- **Well-succeeded problem-solving attempts** – In the above item, we measure the correctness in identifying symptoms. Here, we measure the correctness in problem solving, that is, the next step after recognizing a symptom.
- **Successful Redirection** – This metric approaches the knowledge of an AE on the environment. If an AE does not have enough knowledge to self-configure, self-optimize, self-protect or self-heal, that is, self-manage, than, at least, this AE can recommend other AE which can execute these actions, or a human agent. It is analogous to the case where an AE predicts a problem and redirects jobs to another AE.
- **Time to learn** – It is a prediction of time for an AE to learn a specific item (symptom, solution or characteristic of environment). For this, we use the principle of the Learning Curve (Belkaoui, 1986; Pierson, 1981).

These metrics deal with AE knowledge of a symptom, about its power of solution and about the environment, and finally, on how long it can learn a specific item. Others issues are taken into account, such as:

- **Running Time** – This metric represents the stability of an AE, such as the running time of the resource.
- **Reliability** – It is the time among problems.

With all of these parameters, we can measure the expertise of an AE in a specific issue and, as people, rank the AE which has it. The result of this search is an ordered list with these criteria. The metrics of “Running Time” and “Reliability” are not used to measure the expertise of an AE, but they are comparison criteria.

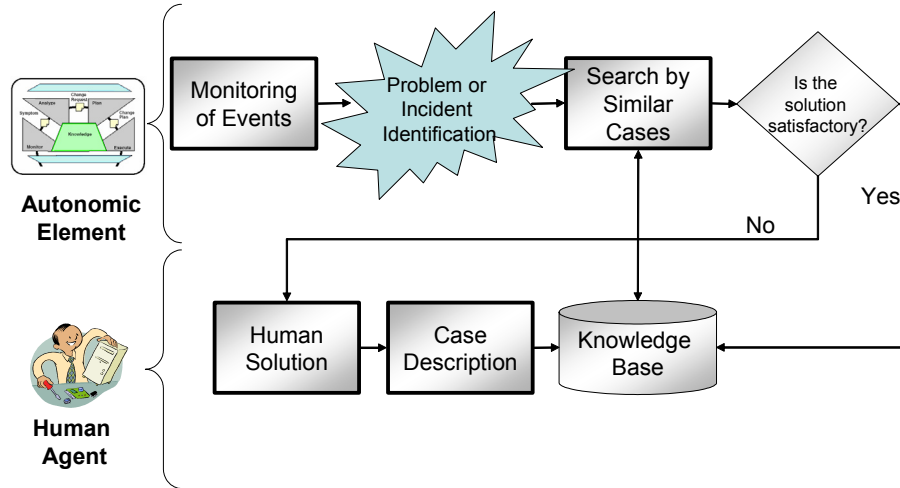
### 3.1.6 Collaborative Filtering Services

In this service, documents are recommended to a new user based on the stated preferences of other similar users and communities. This module produces personal recommendations by computing the similarity between a user’s preference and that of other people. The underlying assumption for the collaborative filtering approach is that those who agreed in the past tend to agree again in the future. This module helps technicians or IT managers to evaluate and disseminate technical material and solutions.

### 3.1.7 Reasoning Services



Reasoning about profiling is made in the “Competence Services”. This module is responsible for extending these functionalities in order to infer cases of solutions, provided by the use of Case-Based Reasoning approach, as show in Figure 5.



**Figure 5 – Case-Based Reasoning Process in GCR**

The case-based solutions engine (for us, a solution is represented by a case) tries to retrieve past cases whose symptom lists are similar in nature to that of the new case and suggests solutions based on the best matching for retrieved cases. So, the process is:

- When an AE detects a problem or an incident, it retrieves the most similar case (or cases) comparing the new case to the library of past cases;
- Reuse the retrieved case to try to solve the current problem;
- If the case is satisfactory and can be reused, this information (association Symptom X Case) is stored in Knowledge Base;
- If not, a human agent can revise and adapt the proposed solution if necessary. The human agent can describe a new case/solution, too.
- Retain the final solution as part of a new case.

There are a variety of different methods for organizing, retrieving, utilizing and indexing the knowledge retained in past cases. Retrieving a case starts with a (possibly partial) problem description and ends when a best matching case has been found.

### 3.1.8 Analysis Services

Some tools are used for observing knowledge evolution, the evolution of communities and comparative analysis by employees, departments and organizations such as:

- How were employees’ and AE’s knowledge developed during a period of time?
- Which competences are more broached in a community?
- How has the knowledge been added in the communities in the last years?

- Which problems were more often mentioned in the communities?
- Which is the most important employee in a community?
- Which area is losing value, that is, is not being discussed nor has no publications about it?
- What are the symptoms that do not have identified problems and solutions?
- And others...

### 3.2 GCR Development

The GCR is a web environment and it has been developed in IIS, using MS-SQL Server as database. Nowadays, its status is as shown in Figure 6.

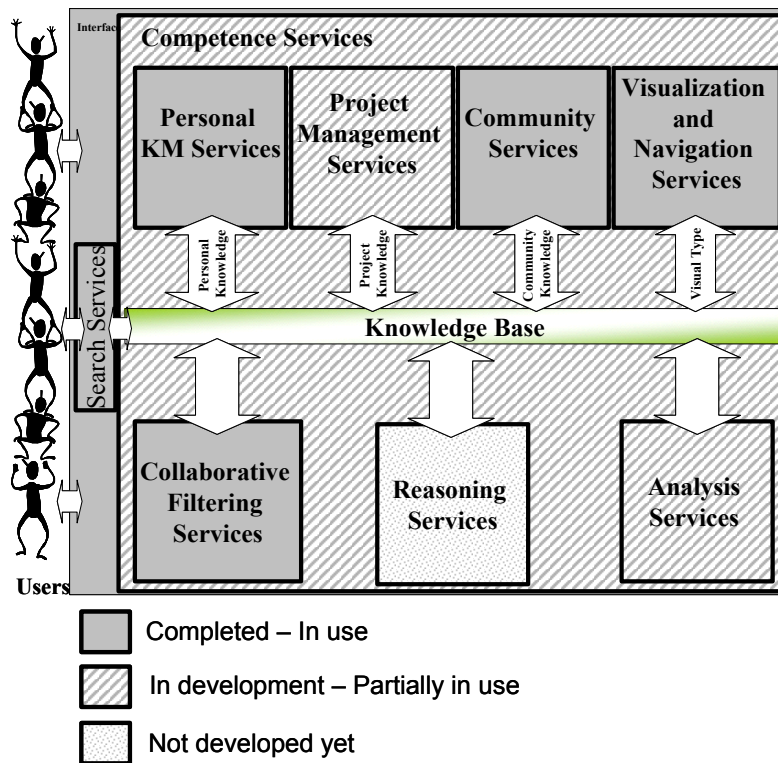


Figure 6 – The GCR Status

The modules of Personal KM Services, Community Services, Visualization and Navigation Services and Collaborative Filtering Services are completed and available for use.

The module for Project Management Services is partially developed allowing project management and knowledge dissemination, but only total workflows can be reused. Now, we are developing the partial reuse of workflows.

Competence Services deal only with human competences. Now we are implementing AE-related services. The same goes for Analysis Services.

### **3.3 GCR and Knowledge Management**

Analyzing the GCR with the KM processes by Stollenwerk (2001) we can understand its contribution for a KM approach in AC, as follows:

- Identification – The module for Competence Services indicates the competences which can be found in the organization, and also indicates Weaknesses and Strengths.
- Capture – Personal, Project Management and Communities Services help in capturing and structuring the knowledge in the organization.
- Selection and Validation – Search Services, Collaborative Filtering Services and Analysis Services aim at the process of knowledge filtering, evaluating and customizing.
- Organization and Storage – All knowledge is organized in a Knowledge Base.
- Dissemination – The flow of knowledge is made by all modules.
- Application – The application of knowledge is made in the shape of projects.
- Creation – The module of Reasoning Services is responsible for the creation of new knowledge.

### **4. Conclusions and Future Work**

In this work we envision an environment to provide some tools aimed at the Managed and Predictive levels of Autonomic Computing and, to providing resources to higher levels to manage and deal with autonomic elements.

Currently, the GCR is a centralized-base environment. As future work, we will develop the other proposed modules and we envision extending it to a distributed scenario. Moreover, we will do experiments to measure how much the GCR is contributing for the AC scenario.

### **5. Acknowledgement**

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