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# Collective intelligence to solve creative problems in conceptual design phase

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In industry, there is an interest in the collective resolution of creative problems found on the phase of conceptual design. In this work we introduce an information-based software framework for collaboration in the problem resolution process. This framework proposes the implementation of techniques from the collective intelligence research field in combination with the systematic methods provided by TRIZ theory. Both approaches are centered in the human aspect of the innovation process, and are complementary. While collective intelligence focuses on the intelligence or behavior that emerges in collaborative work, the TRIZ theory is centered in the individual's capacity to solve problems. The framework's objective is to improve the individual creativity provided by TRIZ method and tools, with the value created by the collective contributions. This work aims to expand the horizon in the field of computer aided innovation (CAI), to the next evolutionary step called Open CAI 2.0.

## 1. Introduction

In the industrial field, innovation represents a key element for economic success. Although there is not a consensus about its definition, it is possible to describe innovation as the implementation of a new or significantly improved product (goods or services), process, marketing method, organizational method in business practices or workplace organization that gives significant advantages to a firm on a market. In order to put into practice this concept, it is

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necessary to define a process that allows to lead from an idea or a need, up to a product in the marketplace; going through different phases such as design, production and marketing. In this paper we mainly focus on product and process innovation.

As reported by Dieter [1], design is a critical phase because the decisions taken in this stage could affect up to 80% of the total manufactured product cost. But product design is not a single activity; instead it is the organization of different activities forming together the product design process. In general this process involves the following phases: (a) starting decision, (b) preliminary design, (c) detailed design and final design.

It is acknowledged that conceptual design (first part in preliminary design) is perhaps the most creative, and difficult phase to achieve. In this paper we introduce the elements for a framework, which is still under development, to enhance the creativity of the participants in the conceptual design phase. The core idea of this framework is to combine the use of collective intelligence, a systematic methodology for problem solving and the functionality that the Web as a platform provides, in order to propose an environment for enhancing creativity through social collaboration.

## 1.1. Creative conceptual design

According to Wang et al. [2], conceptual design is perhaps the most important task in product design. Dieter [1] identifies this phase as the one that involves the most uncertainty, requires the most creativity and the coordination of different agents. To deal with these creative efforts, engineers use different methods, either by manual or computational means.

In [3], the authors appoint the importance of using strategies for improving creativity in conceptual design. According to [4], creative conceptual design has the following characteristics: (a) the statement of an unresolved and poorly defined problem, (b) the problem has a number of contradictions, (c) the achievement of a new solution, (d) and finally the construction of new knowledge. Usually to solve inventive problems or generate ideas in conceptual design, engineers use traditional methods such as: concept-knowledge theory, brainstorming, and trial-error. Nevertheless, these methods have certain drawbacks: randomness, the lack of systematization and the relay on individual talent. From a systematic perspective, innovation can be addressed through a controllable and creative thinking method. To remove existing barriers in traditional methods, the Theory of Inventive Problem Solving (TRIZ) gathers a set of methods and concepts to systematize innovation. Compared to other methods, the advantage of TRIZ is that it is a heuristic based on scientific knowledge and the study of millions of patents [5].

## 1.2. Collective design approaches

The high interdisciplinary in conceptual design involves collaboration from different agents (e.g. customers, designers and engineers). In this context, information and communication technologies provide the space for information exchange and creative interaction [6]. For example, in [2] Wang et al. proposed a paradigm shift in conceptual design to adopt a more pragmatic and aggressive approach through collaboration. In their proposition artificial intelligence and information technologies are the support and impulse for collaboration.

For Nieto and Santamaría [7], collaboration with suppliers, clients and research organizations have a positive impact on the novelty of innovation. Nieto and Santamaría also suggest the integration and the management of internal and external knowledge to improve the levels of innovativeness and competitiveness. Therefore, collaborative innovation enables to access to external sources of technological knowledge and skills. Nevertheless, the collaborative aspect in innovation not only represents a paradigm shift in the conceptualization of the innovation process, but also requires the support of collaborative technologies [8], [9].

Figure 1 describes the development of the tools to support collaborative innovation. It is possible to identify the change from the use of stand-alone applications to the use of technologies and techniques enhancing social interactions. Moreover, this evolution implies the emergence of "weak ties" between different participants. According to Caseau [10], weak ties are important in a company because they allow the collaboration of employees whom normally are not in contact, as well as promoting collective intelligence.
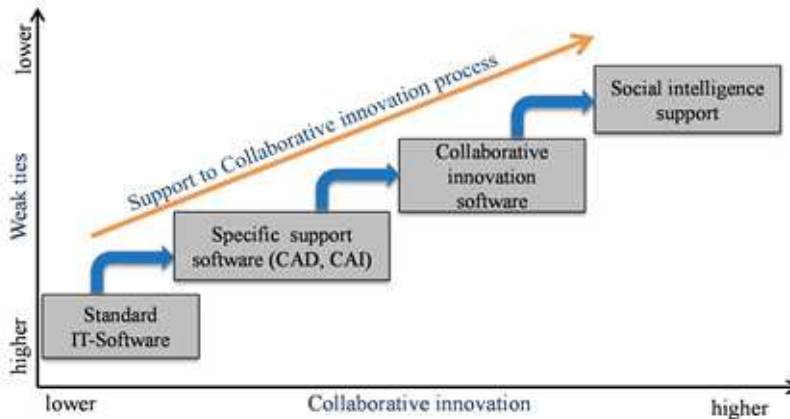
Figure 1. Evolution of collaborative innovation IT-support

*1.3. Open CAI*

According to Leon [11], Computer Aided Innovation (CAI) is the research field that has leaded the efforts throughout the last decades to develop computer solutions in order to support the different activities in the innovation process. Based on Leon's work, it is possible to describe CAI as a discipline in Computer Aided technologies influenced by innovation theories to develop systems using Information– Communication Technologies (ICT) with the goal of assisting enterprises through any stage or the entire innovation process.

Recently, two major changes are driving the evolution in CAI tools. The first one is the technologic aspect based on the advantages that the Web 2.0 offers as a platform. The second one is the management strategy known as the Open Innovation paradigm [12], which consists in opening the innovation process to the participation of external actors and the inclusion of external knowledge. In this scenario, Hüsig and Kohn propose the concept Open CAI 2.0 as the next evolutionary step on CAI development [9]. They define Open CAI 2.0 as "*a category of CAI-tools that use technologies following the Web 2.0 paradigm to facilitate open innovation methods in order to open access of organizations to a large audience of external actors and enable them to interact in different activities of the innovation process*".

The framework discussed in this paper is a prototype following the principles of an "Open CAI 2.0 tool". The main focus of our work lies in the adoption of a systematic innovation process that integrates the capitalization of previous experiences in a collaborative environment. Gathering collective intelligence is considered in this framework as the key element to overcome the obstacles created by the individual cognitive limits typical of a creative activity as it is the preliminary design.

## 2. Collective intelligence in the industrial field

Collective intelligence (CI) has existed since humans started to bring together intellectual efforts to develop specific tasks. Nowadays, industries start to focus on immaterial elements to define the firm value (i.e. brand portfolio, employee's life quality, intelligence emotional). From these elements, collective intelligence is a kind of intelligence that emerges from the synergy of individual creative efforts when a cognitive task (e.g. collaborative innovation) takes place [6]. This synergy is important in new product development because in order to reduce time-to-market and to improve the success possibilities of a product, the innovation process should not depend on the skills of one person.

According to Zara [13], the challenge of collective intelligence and knowledge management is how to improve the collective efforts in order to be better than individual efforts. Zara defines collective intelligence as "*the capacity to join intelligence and knowledge to achieve a common objective*". Collective intelligence takes a new dimension with the incorporation of the computers. For example, the Center for Collective Intelligence at the MIT works

developing systems to connect people and computers so that collectively they act more intelligent [14]. In another example, Innocentive is presented as a platform that connects people with innovation problems to solution providers around the world, with the aim to unleash human creativity to solve problems that matter to business and society [15].

## 2.1. Social Web

The discussion about collective intelligence leads to consider the social behavior involved. The Web 2.0 as a platform improves the performance of human interactions, creating new services known as social networks. According to Caseau [10], a social network is a graph that represents the interaction between actors. In the graph the nodes are the actors and the edges are the interactions.

It is possible to face the challenges that collective intelligence imposes on the innovation process by using social networks. In fact, Social Networks allow interaction of different users who do not know each other; giving rise to the network effect phenomenon [16]. One particular case of social networks is the Collaborative Innovation Networks (COINs). Gloor [17] defines COIN as "*a cyber-team of self-motivated people with a collective vision, enabled by the Web to collaborate in achieving a common goal by sharing ideas, information, and work.*"

Relying on the sharing and cooperation architecture provided by Web 2.0 technologies, it is feasible to deploy applications using collective intelligence techniques. The model in Figure 2 represents the users' interactions to gather collective intelligence from a Web application. The application should aggregate the content in models. The aggregation allows to learn from other users contributions. Finally, the user rates or recommends relevant content.
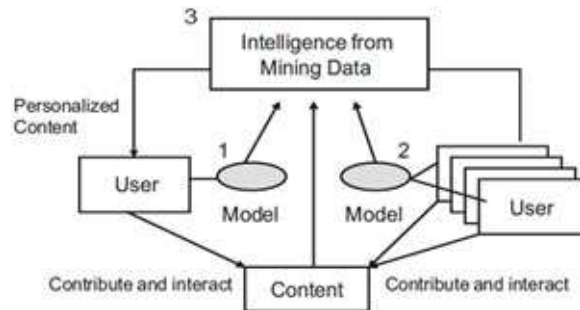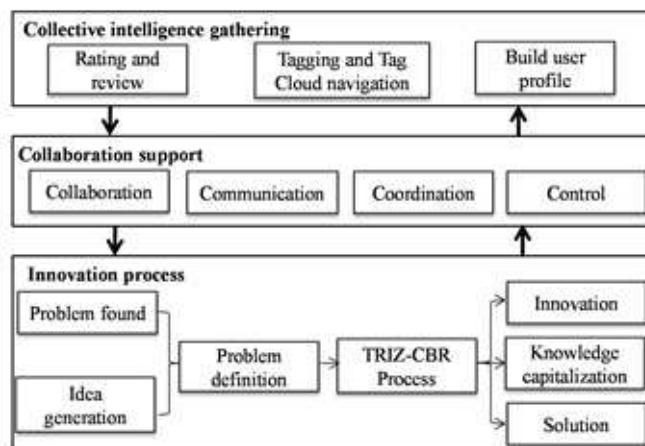


Figure 2. Model of Collective Intelligence [18]



Figure 3 Framework core components

## 3. A new framework for improving conceptual design using collective intelligence

The techniques that were integrated in our framework to improve creativity in conceptual design are focus on harnessing the kind of collective intelligence that emerges from a Web 2.0 application [18].

Figure 3 introduces the way in which our framework's core is organized, and Table 1 generally describes each level. During operation, the different process stages are executed following an asynchronous pattern, namely, each user works on the data separately within a shared resolution space, and the activities assigned to different members are achieved at distinct times. The framework objective is to integrate different aspects in order to: gather collective intelligence, support collaborative work and implement a problem resolution process. A more detailed explanation of each level is presented below.

Table 1 Level characteristics

| Module | Description |
| --- | --- |
| Innovation process | Exploits the most utilized (and easy to use) TRIZ concepts and tools combined with CBR in the model TRIZ-CBR. |
| Collaboration support | This module supports the four basic operations in a collaborative environment [19]: 1) Communication among various users; 2) Coordination of users' activities; 3) Collaboration among user groups on the creation, modification and dissemination of artifacts and products; and, 4) Control processes to ensure integrity and to track the progress of projects |
| Collective intelligence | Propose the use of rating, tagging and building user profile to extract the tacit knowledge that arises from the user's interaction in the collaborative innovation process |

### 3.1. Model TRIZ-CBR

The model TRIZ-CBR [20] organizes the innovation process to assist users in the resolution of technical or physical contradictions. This model considers the integration of the TRIZ tools and the Case- Based Reasoning (CBR) technique in order to provide a resolution process. The resolution process is capable to guide creativity to generate innovative solutions, at the same time that it stores, indexes and reuses knowledge in order to accelerate the innovation process.
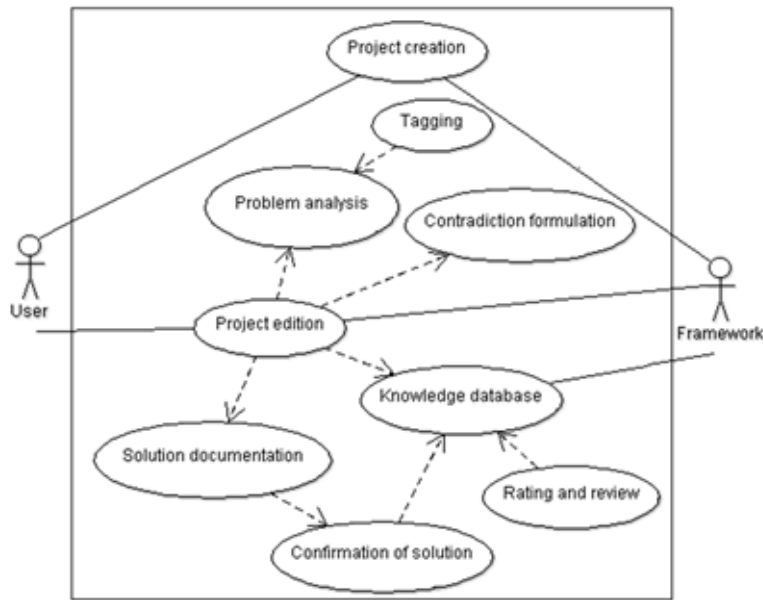
Figure 4 Framework functionality

The framework functionality is presented in the Figure 4 using a Unified Modeling Language (UML) diagram. The resolution process starts when the user creates an entity called *project*. A project is used for structuring all the information aspects concerned with the process. Once the project edited the user has access to the options in order to update any of the project characteristics through dialog components.

The functionality follows a process based on the model TRIZ-CBR. The stages that compose this process are: Problem analysis, Contradiction formulation, Knowledge capitalization and Solution documentation. For example, Figure 5 presents the dialog box to make the description about the problematic situation. The description for each option in the framework is presented next.

*Problem analysis*: According to TRIZ theory, when using contradiction matrix, the user should do an analysis with the single purpose to generate, infer, complete and collect information about the problematic situation. Guided by different TRIZ tools, this section is divided in four stages: General description, System description, Resources identification and Ideal Final Result (IFR).

*Contradiction formulation*: The contradiction is one of the central and most important concepts in TRIZ classic concepts; it is defined as the condition in which two demands or requirements of a system are mutually exclusive but must be assosiated to achieve the same objective [21]. The implementation of this tool, based on a model proposed by Altshuller and Clarke in [21], is with the aim of assisting the user to identify and document the contradiction. Once the user identifies and saves the contradiction, the next step is a query in the knowledge database.
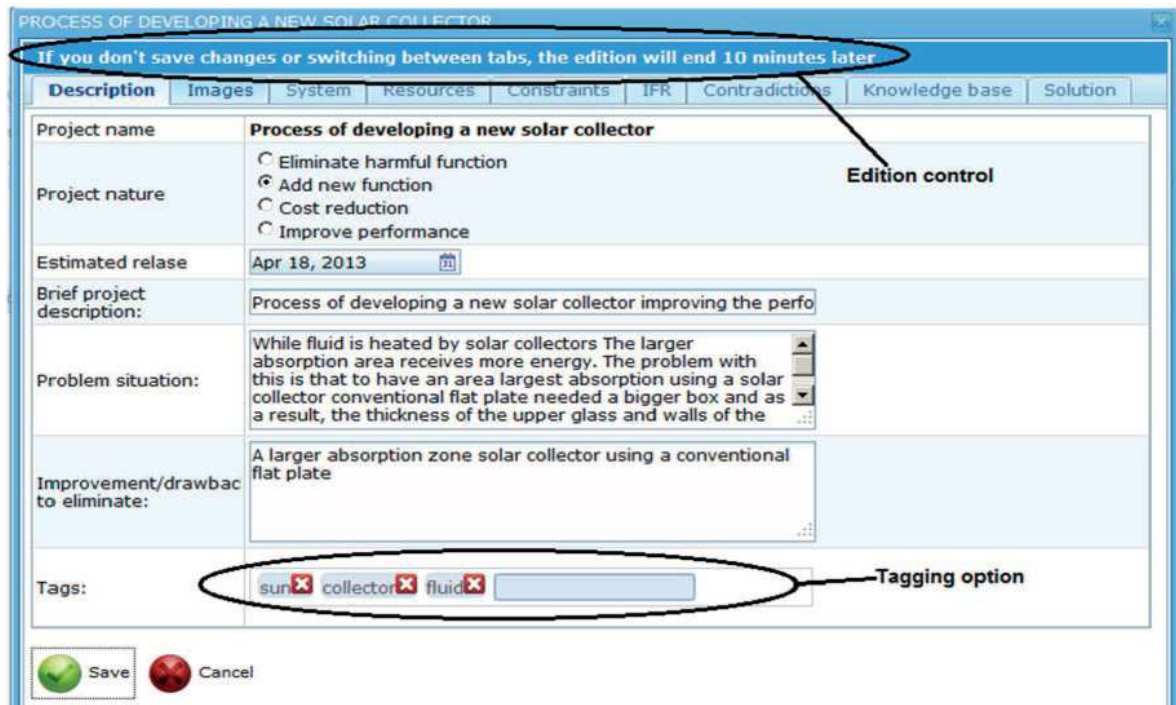
Figure 5 Problematic situation dialog

**Knowledge capitalization**: In this option the user accesses the knowledge database. This database stores previous cases which have been solved either as a success or a failure. For its development, we have used the concepts of a CBR [22] and it is implemented using jCOLIBRI library [23]. After retrieval with a specific similarity measure and the Nearest Neighbour Algorithm, the system gives a list of most similar cases ranked in order of importance. Then, two options are possible for printing all the information related with the case (e.g. General description). Finally, when there is not a similar case the user follows a sub-process in order to solve the contradiction from scratch using the TRIZ resolution principles.

**Documentation of solution**: The last step in the process of problem resolution is documenting the solution. In this stage the user describes in the best possible way the achieved solution. This section is organized in three stages: proposed solution, implementation and details about involved resources. Finally, when a user confirms a solution certain step of the framework generates and stores a new case in the CBR database in order to the coverage of the problem space but also to update the knowledge in the database.

### 3.2. Collaboration support

In the study of innovation through collaboration, the process – as a conceptual object or tool- has a central role because it arranges the activities and actors.

The collaboration process that we propose is centered in the aspects to allow different actors cooperate within a common environment that controls information integrity. These aspects are:

- To provide tools in order to facilitate the communication among users.
- The coordination of activities performed by users.
- To allow users collaboration to create, edit and share projects.
- To allow the creation of collaboration groups.
- To ensure information integrity and keeping the progress tracking.

The actors involved in the process are: the project owner, the project collaborator and the mutual exclusion control.

The Figure 6 is a model in Business Process Model and Notation (BPMN) to describe the collaboration process. In certain way, the project owner is who has more control in the management of a project. After the project creation, he is responsible to create collaboration groups and share the project. Then, to share the project is through an invitation generated by the project owner. In the task "Edit project", the user access to the innovation process described in section 3.1. In the edition, the collaborator accesses the same options to modify the project as the project owner. When a user edits a project the mutual exclusion control blocks the project resource in order to maintain information integrity. The mutual exclusion finishes when the user ends the edition, or by the mutual exclusion control when the timer is over. Then, the project resource is released.
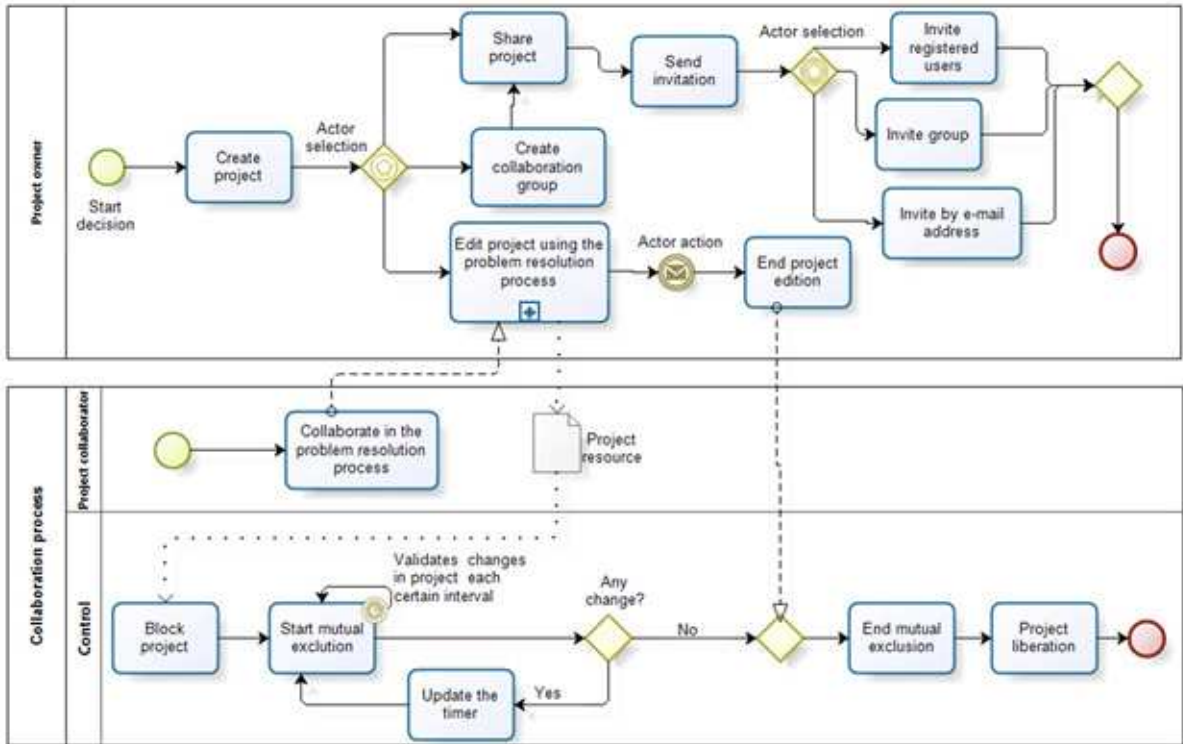
Figure 6 Collaboration process

## 3.1. Collecting intelligence in collaborative innovation

In the conception of our platform, we consider the relation between the problem formulator and the community as follow: a social relationship and a conceptual relationship (see Figure 7). The social relationship appears when a user collaborates with other users to solve a problem. The conceptual relationship emerges when users create elements that we call "knowledge components". The knowledge components are the content users create either by using TRIZ methods or by using domain knowledge to implement a particular solution. The use of tags and reviews enrich the knowledge components as well as they help to create the conceptual relations. The model in Figure 7 considers the user's capacity to learn from their interactions and contributions in a form of feedback (reviews).

The architecture of participation is not enough to harness the intelligence from the collective effort in a Web application. In addition, Figure 7 presents the mechanisms to implement collective intelligence that we identified from [20]. The mechanisms to improve our platform are: tagging, cloud navigation, reviews, and building user profile.
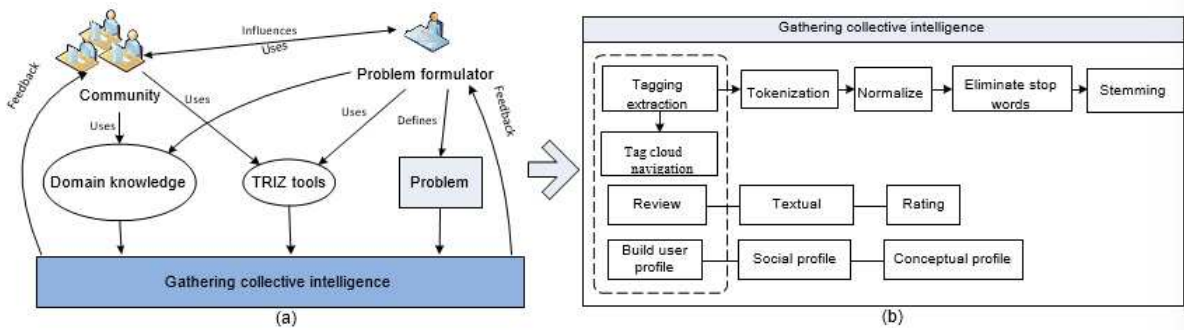
Figure 7 Architecture of participation for gathering collective intelligence

**Tagging:** There are two possibilities to generate the tags: manually or by a process of tags extraction. In the manual option, the user introduces the tags or annotations to add metadata in problematic situation analysis to describe the project. In Figure 5 is possible to appreciate the option for manual tagging. The automatic process for tag extraction, as proposed in [16], is based on the typical steps involved in text analysis (Tokenization, Normalization, Elimination of Stop words and Stemming) from free-text fields.

It is worth mentioning that functionality for gathering collective intelligence is not completed. There is a work in process; nevertheless aspects about this development are pointed out in perspectives.

## 4. Conclusion and Perspectives

### 4.1. Conclusion

Our findings suggest that to achieve a real collaborative innovation in an open context, it is necessary to overcome several barriers, in this paper some of them have been tackled: social interaction, knowledge management and the definition of an innovation process based on problem resolution. A solution that integrates these elements using the Web 2.0 platform was described.

The concepts from collective intelligence introduced in this article expose the possibilities to improve participant's creativity in the phase of conceptual design. The collective intelligence provides a way to expose knowledge that is otherwise hidden in a collective environment. For example, bubbling up interesting content or dynamic content classification.

In order to develop a more complete platform, it is necessary to take advance of the most recent approaches provided by information technologies to master knowledge management in collaborative environments. Semantic technologies seem to provide powerful and practical mechanisms to develop this functionality.

This work is not free from limitations. One drawback is that the success for the framework depends on the interest and participation of the actors involved. By considering this limitation, we develop an important effort to take into consideration guidelines for usability and collaboration within Web 2.0 applications.

Finally, it is required the validation through the internet or an intranet network. This validation will be realized in a case related with the process engineering domain.

### 4.2. Perspectives

Although the contradiction matrix is an important tool, its utilization is not easy and relies on the user's skills. This limitation could be overcome using an automatic method in order to scan free-text and find the specific technical parameters to formulate the contradiction [24].

In relation to the work in progress, we intend to develop missing functionality about collective intelligence. However, it is possible to present some of the characteristics expected.

Firstly, incorporate tag clouds. This component helps the user to make a rapid search using the tags concepts generated manually by the users or the process for tags extraction.

Secondly, provide review functionality. The reviews are useful to quantify the quality of the content generated by the users. In the platform the reviews are focused on problem solutions, and they could be of two types: textual and rating. Both kinds allow the users to provide an instant feedback about the solution's relevance. The rating option has an advantage over the textual review because the information provided is quantifiable and used directly.

And lastly, create a user profile. The importance to build a user profile is because it allows the framework to provide more relevant and personalized information. Our framework proposes to generate the profile base on the content user generates and the social interactions. The use of TRIZ tools and domain knowledge via tag extraction are the base to build a profile of concepts. The collaborations between the user and the community are the base to build the social profile. For example, in [25] the authors propose to use the social profile to find possible collaborators for a particular project in a recommendation system.

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