

Chapter 9

Collaboration Framework for TRIZ-Based Open Computer-Aided Innovation

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Abstract In the current industrial context, there is an increasing interest in the collective resolution of creative problems during the conceptual design phase. With collaboration, companies can expect to facilitate aggregation of multi-intelligence and knowledge for the proposal of new inventive solutions. Recent advances in theoretical approaches to innovation management as well as in information and communication technologies provide a more structured knowledge-driven environment for inventors, designers, and engineers. As a result, a new category of tools known as computer-aided innovation (CAI) is emerging, with the goal of assisting designers in their creative performance and of effectively implementing a complete innovation process. This chapter proposes a next evolutionary step for CAI, arising from two major recent developments: one coming from the advances in information and communication technology possibilities commonly referred to as “Web 2.0” and the other coming from a strategic paradigm shift from closed to open innovation. To go further, in this work we introduce an information-based software framework to collaborate for inventive problem solving. This framework proposes the implementation of techniques from the collective intelligence research field in combination with the systematic methods provided by the TRIZ theory. While collective intelligence focuses on the intelligent behavior that emerges in collaborative work, the TRIZ theory concentrates its attention in the individual capacity to solve problems systematically. The framework’s objective is to improve the individual creativity provided by the TRIZ methods and tools, with the value created by the collective contributions. This contribution highlights the importance of knowledge acquisition, capitalization, and reuse as well as the problem formulation and resolution in collaboration.

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9.1 Introduction

One core challenge in the strategic management of technological innovation is the diverse nature and location of sources for innovation. As Schilling (2012) argues, innovation can originate from different sources: individuals, universities, firms, and nonprofit or government-funded entities. However, according to the last author, the most important source for innovation arises from the linkages between these different sources. Consequently, enterprises require strategies and tools to explore the different sources and their linkages to improve their innovation capacities and capabilities.

Currently, advances in theoretical approaches to innovation as well as in information and communication technologies (ICTs) provide a more structured knowledge-driven environment for inventors, designers, and engineers. As a result, a scientific research field known as computer-aided innovation (CAI) is emerging, with the goal of assisting designers in their creative performance and of effectively implementing a complete innovation process throughout the whole product or process life cycle. Within the front end of the innovation process, this chapter proposes an evolutionary step of CAI toward the concept of Open CAI 2.0 previously defined by Hüsigg and Kohn (2011). Open CAI 2.0 arises from recent developments on two drivers: (1) one coming from the advances in technological possibilities in the software field commonly referred to as “Web 2.0” and (2) the other coming from a strategic paradigm shift from closed to open innovation. Therefore, this work proposes an Open CAI 2.0 framework which relies on the coupling between the innovation TRIZ theory and case-based reasoning. This CAI tool aims to support the generation of inventive technological solutions through a problem-solving process that needs a reformulation of the initial problem to build an abstract model of the problem. This work also highlights the importance of knowledge acquisition, capitalization, and reuse as well as the problem formulation and resolution in collaboration.

9.1.1 *Industrial Context*

In the scope of the knowledge-based economy, the management of technological innovation is a critical aspect toward the success of the modern industry. As Laperche et al. (2011) argue, the capacity to innovate has evolved to become the engine of competition and industry competitiveness. Therefore, the design and industrialization of new and more complex products in a shorter time is a challenge for industrialized countries. To cope with this pressure, industries depend on information, knowledge, and highly specialized skills in various domains. Companies are aware of the importance of collaborations with other organizations as the source of specialized knowledge. Such companies consider innovation as an interactive process capable of creating and exchanging knowledge within and outside

the firm’s boundaries. Within this scenario, the methods and computational tools that must face industrial challenges in innovation demand the ability to mobilize individual tacit knowledge toward a more interactive strategy. Such a strategy should also encourage staff skills to develop innovative products in a shorter time, to increase the level of inventiveness of products, and to lower development costs.

9.1.2 From Closed to Open Innovation

Some authors (Hüsig and Kohn 2011; Chiaroni et al. 2011) agree that open innovation shows its efficiency by changing the way in which the enterprises interact with customers and other external actors (suppliers or universities). The interaction is practiced in a more open way to improve their innovative capabilities and to accelerate internal innovation. The scope of open innovation has progressively evolved to lead to the definition of Chesbrough and Bogers (2014): “Open innovation is defined as a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with organization’s business model.” This is contrasted with the “closed” model of innovation, where firms typically generate and develop their own ideas and innovation in isolation. To detail the open innovation concept, Table 9.1 makes a comparison between closed innovation and open innovation. In their contribution to the debate on open innovation, Trott and Hartmann (2009) explain that the dichotomy between closed and open innovation may be true in theory but does not really exist in industry. They have examined the six principles of closed innovation (and by consequence those of open innovation), and they have concluded that the open innovation paradigm has created a partial perception by describing something which is true (limitations of closed innovation), but false in propagating the idea that firms follow these principles.

Table 9.1 Closed innovation versus open innovation (Chesbrough 2003)

Closed innovation	Open innovation
The smart people in the field work for us	Not all the smart people work for us
To profit from R&D, we must discover, develop, and ship it ourselves	External R&D can create value; internal R&D is needed to claim a portion of that value
If we discover it ourselves, we go to market first	We don’t have to originate the research to profit from it
If we are the first to commercialize an innovation, we will win	Building a better business model is better than getting to market first
If we create the most and best ideas in the industry, we will win	If we make the best use of both internal and external ideas, we will win
We should control our intellectual property so that our competitors don’t profit from our ideas	We should profit from others’ use of our intellectual property and vice versa

In the industry, open innovation represents the antithesis of the traditional vertical model in the new product development process, and it is a solution to problems and drawbacks for the design process in traditional hierarchical organizations (Sorli and Stokic 2009). The open innovation paradigm focuses on the use of explicit internal as well as external knowledge to accelerate internal innovation, in opposition to the “not invented here” syndrome.

As a process, open innovation demands a massive effort of knowledge management. It uses the principle that valuable ideas can come from inside or outside the company, but also can go to market inside or outside the company as well; this knowledge flow is often represented by the classical funnel illustrated in Fig. 9.1. However, useful knowledge is widely distributed, a condition that represents a challenge to identify, interact, and take advantage of external knowledge sources and then to integrate it at the core of the innovation process.

9.2 Computer-Aided Innovation and TRIZ

The use of computer-aided technologies facilitates the transition from a closed model to drive the innovation process to a more open approach which includes actors and knowledge beyond the enterprise boundaries. In this scenario, CAI tools are useful to promote collaborative work, to implement knowledge management systems, to perform routine and time-consuming activities (e.g., patents search), and to access external sources of information. CAI is a software-based solution assisting participants in the different stages of the innovation process. In the beginnings, CAI software was mainly inspired by TRIZ methods and tools. However, CAI solutions are progressively evolving and adapting to enterprises' requirements.

In the last years, the development of CAI tools has given birth to different commercial software applications. Some of them are focused on specialized tasks of the innovation process, while others try to cover the whole innovation process. An area of opportunity arises because most of the CAI products concentrate on specific tasks like idea management or patent search and only a few of them consider the whole innovation process. Concerning CAI tools, this work covers only developments oriented to the new product development. Specifically, it includes some TRIZ tools for improving creativity in the resolution of inventive problems.

For Natrass and Okita (1983), humans and computers form a symbiotic relationship in product design. In this relationship, human beings outperform computers in thinking spontaneously and relating disjointed facts and are creative by association. On the other hand, computers are faster, more accurate, and tireless, and they are more efficient in processing huge quantities of engineering data at a time. In the experience of Pollack et al. (2003), humans should be engaged in higher-level forms of creativity, while computers are suitable for lower-level details of design. Since the front end of innovation requires developing a solution with a

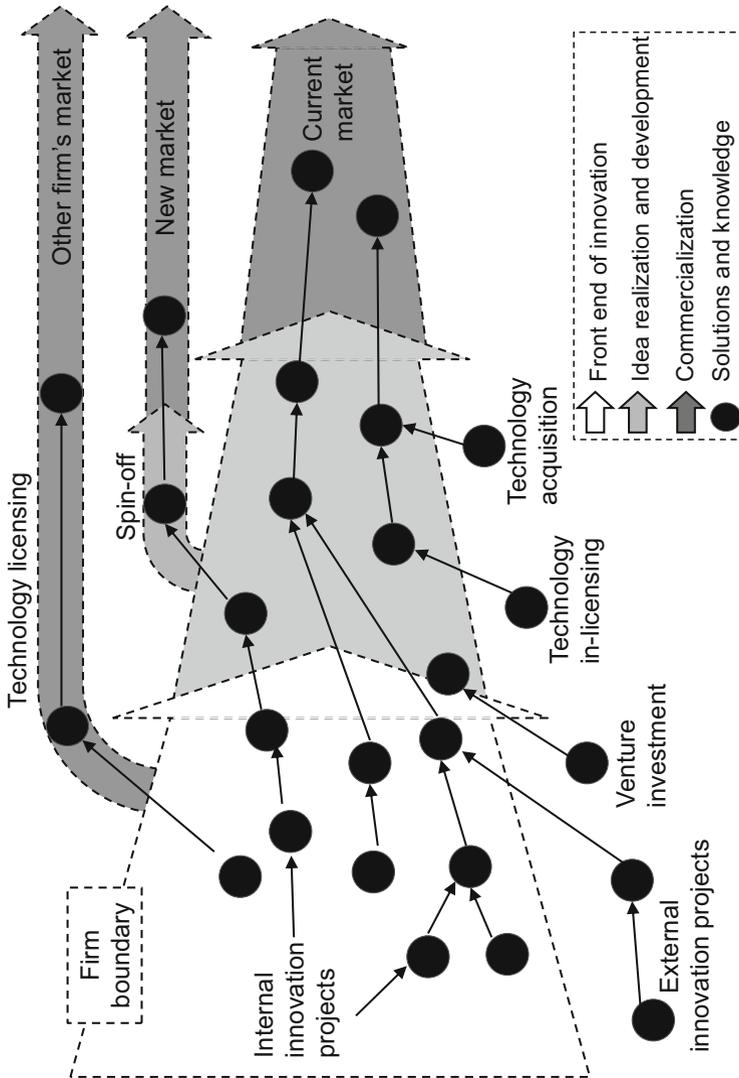


Fig. 9.1 Open innovation model (Herzog and Leker 2011). (C) 2010 Springer, reprinted with permission

high degree of inventiveness and creativity, it is reasonable to expect that humans are the most qualified for this task.

Furthermore, as Giachetti et al. (1997) highlight, engineering design is characterized by a high level of imprecision, fuzzy parameters, and ill-defined relationships. Therefore, the principles of the innovation process need to take into account these imprecisions in design. As observed in Fig. 9.2, imprecision is more important in the early stages of design, because they typically begin with a description

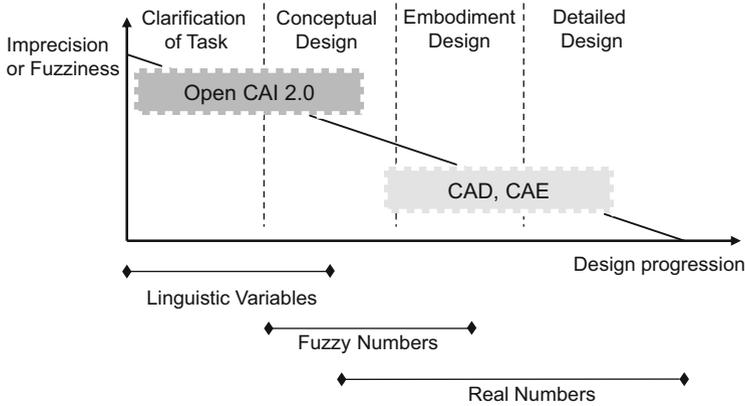


Fig. 9.2 Imprecision level in Open CAI 2.0 (Giachetti et al. 1997)

regarding the natural language statements. At this level, linguistic imprecision arises from the qualitative descriptions of goals, constraints, and preferences made by humans (Giachetti et al. 1997).

To deal with the previous requirements, ICTs supporting innovation processes are evolving simultaneously as are the methods for managing innovation. There is a real interest for ICTs as new ones are continually emerging (Sorli and Stokic 2009). Specifically, the Web technologies are transforming all human activities dependent on information, including social interactions.

9.2.1 Web 2.0 as a Platform for Collaboration

Web 2.0 as a technological driver leads to implement and to take advantage of collaborative workspaces. Indeed, the Web 2.0 technology supports an emerging form of collaboration that can be beneficial for open innovation, based on the many-to-many form of communication. But before understanding collaboration within Web 2.0, it is necessary to make a semantic distinction between cooperation and collaboration. According to Caseau (2011), the main difference between both terms is the degree of organization of the activities between actors. Indeed, collaboration is a fuzzier concept, and the participants do not have a hierarchical organization. Instead, the work is guided by a common objective which is shared by all the members. Both cases require an orchestration of activities, which justifies the definition and the formalization of a model.

For Campos et al. (2006) and Sorli and Stokic (2009), situations of collaboration in the industry seek to facilitate the participation of different actors in activities related to reach a common objective (e.g., solving a problem, designing a new product). Figure 9.3 shows a generic framework with the main activities to consider in collaboration whatever the situation and the collaboration purpose.

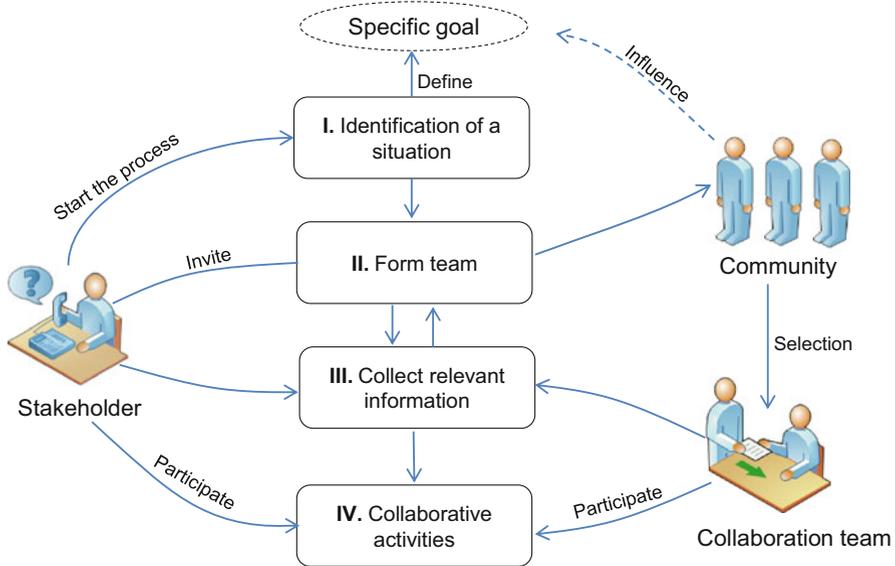


Fig. 9.3 Generic model for industrial collaboration. Adapted from Campos et al. (2006)

For implementing such a framework, Web technologies offer new possible ways to communicate and share information, from the use of the e-mail up to the incorporation of the “architecture of participation” relying on Web 2.0. Building on the Web 2.0 technologies, social network services create new forms of communication, interaction, information sharing, and collaboration. Social networks base their operation in the creation of relationships between participating members (e.g., social or family ties), through the use of ICTs. For Caseau (2011), there is an emerging way to organize collaborative work in the industry, leading to what is known as “Enterprise 2.0.”

Profile diversity in collaboration environments is another element to take into account in the creativity driver. Indeed, to have an efficient collaboration, the community must gather members with various domains of expertise. Consequently, it is important to have a shared technical language which enables participants to bridge the gap between their backgrounds and problem abstractions to exchange information and knowledge. Moreover, the complexity of inventive problems requires a clearly defined language and a step-by-step procedure to transform the initial problematic situation into a solution. The TRIZ theory is probably the most appropriate tool for reconciling concrete and abstract visions of the problem and to facilitate the knowledge exchange between different scientific domains.

9.2.2 TRIZ-Based Inventive Problem Resolution

The evolution of CAI-based solutions also depends on the expansion of the methodologies to assist the creative process of idea generation and problem resolution. According to Ilevbare et al. (2013), different visions exist about TRIZ, either as a methodology, a toolkit, or as a science. Consequently, the multiple approaches lead to confusion on its definition. Moreover, in practice, TRIZ is particularly challenging because the engineering nature of the methodology makes it difficult to adapt for application in a wide range of situations. The lack of standardization in the application also makes the practice of TRIZ difficult. The Algorithm for Inventive Problem Solving (ARIZ) is considered as one of the most powerful algorithms of TRIZ to guide the problem-solving process. Ilevbare et al. (2013) explain that ARIZ is a sequence of logical steps to analyze an ill-defined initial problem and leads to the formulation of a solution by using TRIZ concepts and tools.

Although ARIZ brings together most of the fundamental concepts and methods of TRIZ, it does not have a broad application due to the following reasons:

- It is a long step-by-step guide.
- It is considered as an analytical approach rather than a problem-solving process.
- It is exhausting, especially when the user does not have much time for solving a problem.
- It is required for <1% of all technical problems.

Due to the previous drawbacks, this work studies alternatives to ARIZ. The use of TRIZICS seems feasible as a roadmap to organize the process of problem resolution. In practice, TRIZ tools are organized depending on the problem situation. In this case, it is particularly challenging for inexperienced users to select and apply the appropriate TRIZ tools. Cameron (2010) proposes a standard process, named TRIZICS, to guide the user from the beginning of a problem-solving process to the end. The TRIZICS roadmap is composed of six sequential steps which structure a systematic problem-solving process: (1) identifying the problem, (2) selecting the problem type, (3) applying analytical tools, (4) defining the specific problem, (5) applying TRIZ solution tools, and (6) solutions and implementation. Each of these six steps provides a formal model to define the problem, specifies the limitations, establishes deadlines for a solution, reviews assumptions, and defines the cost, resources, and the implementation plan. TRIZICS offers a basis to integrate classical TRIZ methods and tools in a framework for the development of CAI.

9.2.3 Academic Developments

TRIZ methodology provides the concepts and tools to enhance creativity while providing a logical framework for problem resolution. However, commercial tools

Table 9.2 Academic development analysis

Work	Objective	Advantages	Disadvantages
TREFLE-ENSAM (2003)	To adapt TRIZ tools with functional analysis and to introduce ecological concerns in the earlier steps of the design	<ul style="list-style-type: none"> – Adapted to preliminary design – To develop innovative concepts from existing products 	<ul style="list-style-type: none"> – Brainstorming organization for interpretation and the choice of concept
Cavallucci and Leon (2004)	To establish the theoretical basis to build a CAI tool by interacting with a computer-aided design (CAD)	<ul style="list-style-type: none"> – Formulating theoretical bases to build CAI systems – Defining a generic model adopting a guided design approach 	<ul style="list-style-type: none"> – The proposition to design up a contradiction network is complicated
Cugini et al. (2009)	To improve the product development cycle integrating CAI tools with optimization and product life cycle management	<ul style="list-style-type: none"> – A design tool integrating optimization techniques – Interoperability with CAD environments 	<ul style="list-style-type: none"> – Oriented to incremental innovation – Limited to the use of contradictions
Chen et al. (2009)	To involve nontechnical staff in the innovation process	<ul style="list-style-type: none"> – Highlighting the importance to involve nontechnical department staff – A well-structured process analysis problem can solve the problem and has an action plan 	<ul style="list-style-type: none"> – The interaction between nontechnical and TRIZ practitioners is not defined
Li et al. (2009)	To set up a process of technology innovation based on TRIZ and CAIs according to the characteristics and the existing problem of the manufacturing enterprises	<ul style="list-style-type: none"> – Combination of a classical innovation process with TRIZ tools and CAI technology 	<ul style="list-style-type: none"> – Interested only in product innovation – The problem solving strategy is not detailed
Zhang (2011)	To simulate the thinking process of the human in the innovation to shorten the innovating time	<ul style="list-style-type: none"> – Incorporation of a knowledge discovery system – Proposition of an expert system to accelerate the process of invention 	<ul style="list-style-type: none"> – The process workflow is not clear
Tan (2011)	To apply computer-aided innovation (CAI) systems based on TRIZ to solve some ill-structured problems that appear in an innovation pipeline	<ul style="list-style-type: none"> – An application to solve ill-structured problems in an innovation pipeline – Applying TRIZ in two sub-processes, the input design and the conceptual design separately 	<ul style="list-style-type: none"> – Limited to a two-stage analogy process model
Li et al. (2012)	To classify patents according to the level of inventiveness as defined in the theory of inventive problem solving (TRIZ)	<ul style="list-style-type: none"> – Detailed workflow for a conceptual design activity – Incorporating data mining of patents, natural 	<ul style="list-style-type: none"> – Drawbacks for scaling up the work or putting the proposed method into practice – Increasing the

(continued)

Table 9.2 (continued)

Work	Objective	Advantages	Disadvantages
		language processing, and machine learning	computational burden for processing newly published patents
Hu et al. (2013)	To combine the case-based decision theory approach (to store and reuse knowledge) with TRIZ	<ul style="list-style-type: none"> – Supporting decision making during the design process – Incorporating knowledge management 	<ul style="list-style-type: none"> – Limited to formulate the problem as a contradiction – The process is not organized in phases
Lopez Flores et al. (2015a, b, c)	To explore the use of collective intelligence within the TRIZ deployment	<ul style="list-style-type: none"> – Regarding the collaborative aspect to deploy TRIZ – The use of experience capitalization 	<ul style="list-style-type: none"> – The lack of semantic analysis – It requires tools to facilitate problem modeling

implementing TRIZ are limited to the classic methodology. Therefore, the development of integrated CAI products based on TRIZ tools and modifications to TRIZ are still areas of opportunities that the academic world has taken to propose new evolutions of TRIZ and the development of CAI, as demonstrated in the special issue of the *Computers in Industry* journal in 2011. Table 9.2 presents an analysis of advantages and disadvantages of academic developments; the analysis gives a perspective about CAI looking to propose more global and inclusive solutions. Thus, it is possible to identify two principal evolutions: to advance the methodology and to advance the theoretical foundations of the CAI field.

Table 9.2 documents the interest in the academic community for complementing TRIZ with other approaches. The first case (TREFLE-ENSAM 2003) proposes a tool to integrate TRIZ creativity tools with other approaches such as functional analysis. In other proposals, Cavallucci and Leon (2004) and Cugini et al. (2009) try to have a more inclusive process and interoperable tools covering all the phases of product life cycle management. Regarding knowledge capitalization, Hu et al. (2013) propose to combine TRIZ with case-based decision theory, and Li et al. (2012) incorporate data mining of patents. Finally, as an effort to simplify the use of TRIZ, Chen et al. (2009) propose the involvement of nontechnical employees, and Zhang (2011) tries to simulate the thinking process of humans. As observed, the interest to advance TRIZ and the CAI tools associated is different: from covering the whole product life cycle and the incorporation of knowledge capitalization approaches to trying to make easy the practice of TRIZ for nontechnical employees. However, few academic developments address the collaborative dimension.

9.3 Architecture for TRIZ-Based Collaborative Open CAI

9.3.1 Overview

The description of the functionalities of our proposed collaborative Open CAI 2.0 starts with the presentation of the general usage of operation in Fig. 9.4. The logical basis of the collaborative resolution process consists of orienting the interactions of the involved participants in such a process with a common language, specifically the problem formulation tools provided by the systematic approach of the TRIZ methodology.

The main operations of the general use case are as follows:

- I. The first activity, identification of a situation, corresponds to the description of the problematic situation. The basic information to describe and analyze the problem is as follows:
 - a. Project name and general description
 - b. Clear problem statement
 - c. Images and documents related
- II. The second activity is the composition of the collaboration team. This situation requires identifying specific experts for the problem faced. Two types of search are possible:

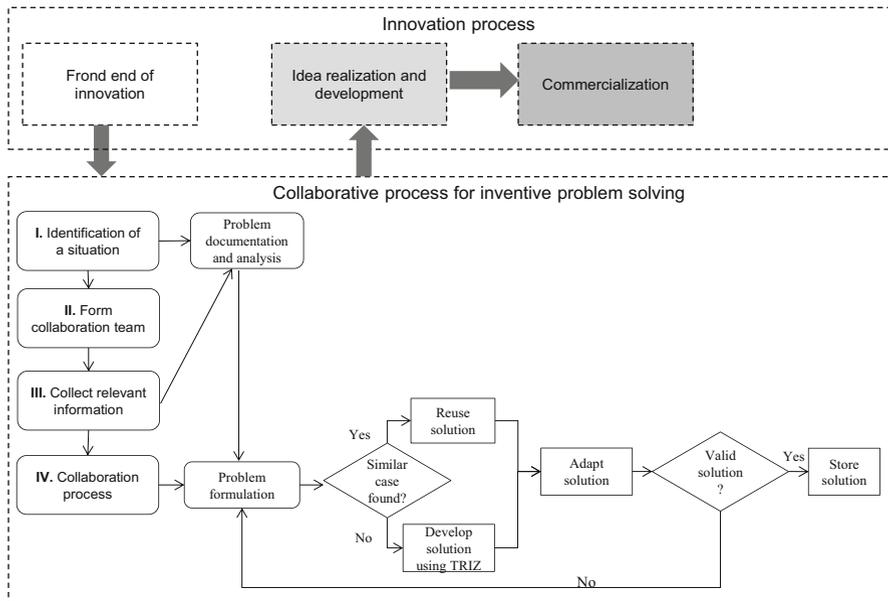


Fig. 9.4 General usage of the collaboration process for problem solving (Lopez Flores et al. 2015a)

- a. Among the group of registered users
 - b. Outside the platform, looking in other sources for the required expertise
- III. Collecting relevant information helps to provide details to make clear the problematic situation. Once the collaboration team is complete, the participants have the option to review and complete the information about the problematic situation.
- IV. The collaboration process uses an asynchronous pattern to coordinate the participations to ensure information integrity. In this phase, it is the hybrid TRIZ-CBR model (our synergy previously developed in Cortes 2006) which drives the collaboration activities.

In this combined approach, TRIZ provides the generic knowledge and the initial structure to generate case indexation. CBR brings techniques to compare and search for a previously solved problem. Thus, this coupling is a way to add memory to TRIZ for the capitalization of new solved cases in inventive design. This synergy combines two types of knowledge: generic from various fields using TRIZ and domain specific through capitalization. Built with the aim to accelerate the design, implementation of such a synergy brings several questions. Indeed, it is neither the use of CBR in inventive design nor the original logic of TRIZ. But the proposed approach offers the possibility to create new knowledge with a limited scope but useful for the generation of a concept with a medium level of inventiveness. This coupling also facilitates the transfer of technological solutions avoiding some pitfalls, thanks to information on the implemented solution. The tool built on this approach facilitates the handling of TRIZ methods and tools. Another advantage is that the knowledge stored in the system could be useful in two ways: in the early design stages (preliminary design) and as a criterion for evaluating the pertinence of proposed concepts or ideas.

Concerning collaboration, the advantage of using the TRIZ-CBR model is that the TRIZ theory is an approach that provides a common language to communicate the problem formulation (Ilevbare et al. 2013). For instance, contradiction and Su-field model are very well-defined patterns with a high level of abstraction. Consequently, they facilitate the creation of problem models which are independent of a specific technical domain. Moreover, the proposed collaboration model aims at facilitating the interaction between TRIZ beginners and experienced TRIZ users.

The software-based architecture is a socio-technical system capable of linking together people having inventive problems (stakeholder) with a community of solution providers. Figure 9.5 provides a description of the proposed service for an Open CAI framework.

- (1) “Stakeholder”—includes, but not limited to, the individual or group of individuals having inventive problems. The stakeholder is responsible to start the collaboration process by sharing an idea or an inventive problem.
- (2) “Inventive problem”—refers to the need or idea imagined by the stakeholder and which is formulated as an inventive problem. An inventive problem is a complex situation that required the transformation of existing technical knowledge for the formulation of new concepts.

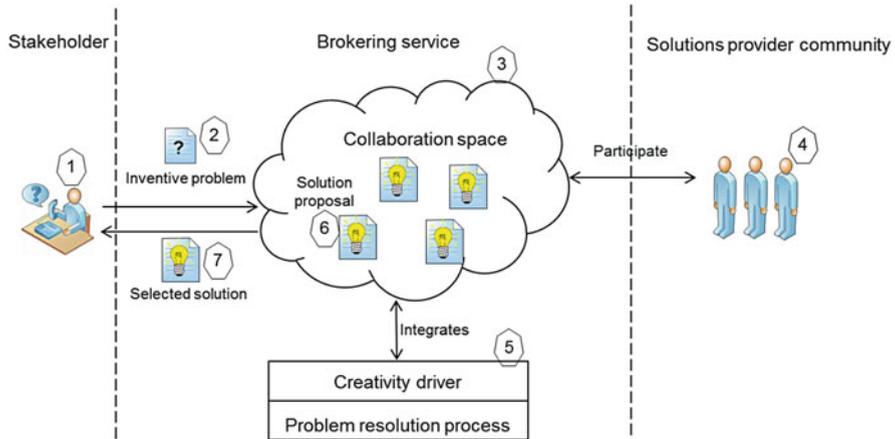


Fig. 9.5 Elements of the crowdsourcing service

- (3) “Collaboration workspace”—is the virtual workspace that relates the stakeholder with a community of solution providers. This workspace includes the workflow to formulate the problem and to develop one or multiple solution proposals following the problem resolution process. It takes into account the collaboration aspects previously addressed in Sect. 9.2.1. Also, the collaborative workspace implements the mechanism to communicate, coordinate, and control the contributions from the involved participants.
- (4) “Solutions provider community”—includes, but not limited to, the group of individuals with the potential to participate in the workflow of the problem resolution process. The community is composed of members having different technical profiles, like TRIZ practitioners.
- (5) “Problem resolution process”—is the sequence of steps that coordinates the search for a solution to a problematic situation. In this work, the process is organized following the principles of the tools proposed in the TRIZ theory and the model TRIZ-CBR.
- (6) “Solution proposal”—is the formulation of a possible solution for a specific inventive problem. They are formulated through the different phases of the resolution process. To promote participation, the collaborative workspace allows for one inventive problem to have multiple solution proposals.
- (7) “Selected solution”—is the creation of new concepts or new relationships between existing concepts to propose a new conceptual design of a product, a process, or services. It is the stakeholder who takes a decision about the solution that best fits the requirements for his specific inventive problem. Currently, the selection of conceptual solutions is subject to the stakeholder criteria and expertise. However, it is feasible to improve the evaluation with a method that highlights the areas of conflict in the initial decisions, and use the Pareto front to make a more objective selection (Chinkatham and Cavallucci 2015).

9.3.2 Framework Architecture

To organize the different elements of the proposed framework, Fig. 9.6 introduces a three-level structure. During operation, the different process stages are executed following an asynchronous pattern, namely, each user works on the sub-activities in the problem formulation activity separately in time within a shared resolution space, and the activities assigned to different members are achieved at distinct times. In the following, we provide a description of the operations of each level.

9.3.2.1 Innovation Process

In this work, we use some of the elements of the TRIZICS roadmap to propose a simplified version to organize the classical and modified TRIZ tools into two phases: problem description and analysis and problem formulation and solution. The application has two phases. This segmentation consents some benefits: it allows the participation of TRIZ inexperienced users as well as TRIZ experts in the same roadmap. As illustrated in Fig. 9.7, problem description and problem analysis include the use of classical tools oriented to a broader audience of

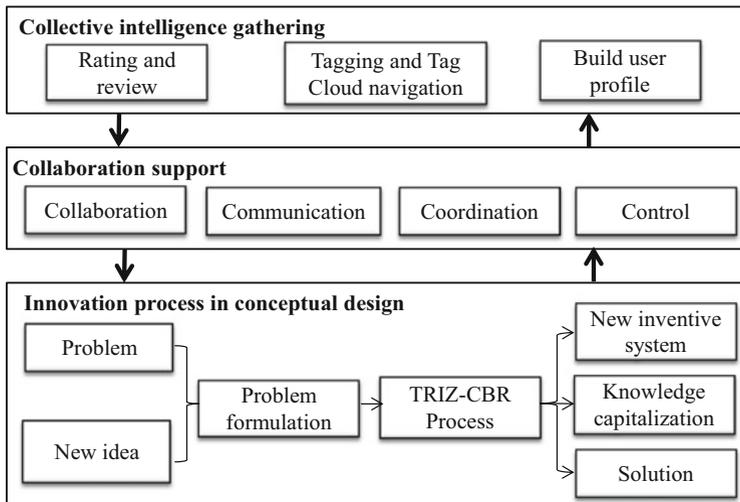


Fig. 9.6 Organization of theoretical elements in our Open CAI solution (Lopez Flores et al. 2015b)

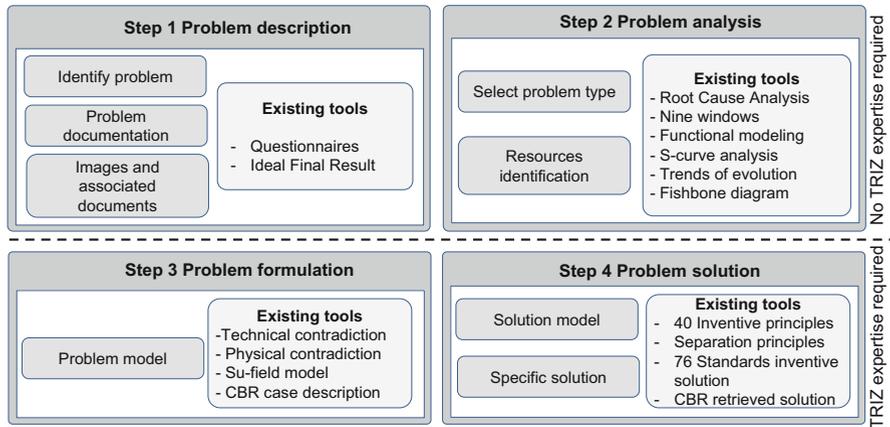


Fig. 9.7 Problem resolution roadmap

non-TRIZ practitioners. Problem formulation and problem solution are tools that require expertise in the use of TRIZ. This versatility in the roadmap aims to create the conditions to promote an active participation of the two types of users. Additionally, the workflow is affected by the CBR cycle, as it was previously described in Cortes (2006) about the interest and strengths of the hybrid model TRIZ-CBR.

9.3.2.2 Collaborative Resolution Process

Figure 9.8 describes the operation of the collaborative workspace, using BPMN notation. The actors involved in the process are the stakeholder (project creator), the solution provider(s), and the control system. After the project creation, the stakeholder is responsible for sharing the project, either to all the community or a collaboration team. Then, the mechanism to share the project is realized through an invitation generated by the stakeholder. The operation of the collaborative workspace presented in Fig. 9.8 aims to maintain information integrity when different participants collaborate on the same project. The mutual exclusion finishes when the user ends the edition or by the mutual exclusion control when the timer is over. Consequently, it takes into account the following aspects:

- To coordinate the activities performed by users
- To allow users to create, edit, and share projects
- To allow the creation of collaboration groups
- To ensure information integrity and to keep tracking the progress

The project is a structure that contains all the information related to a problem. Once a project is created, the owner describes the problem situation, adds relevant

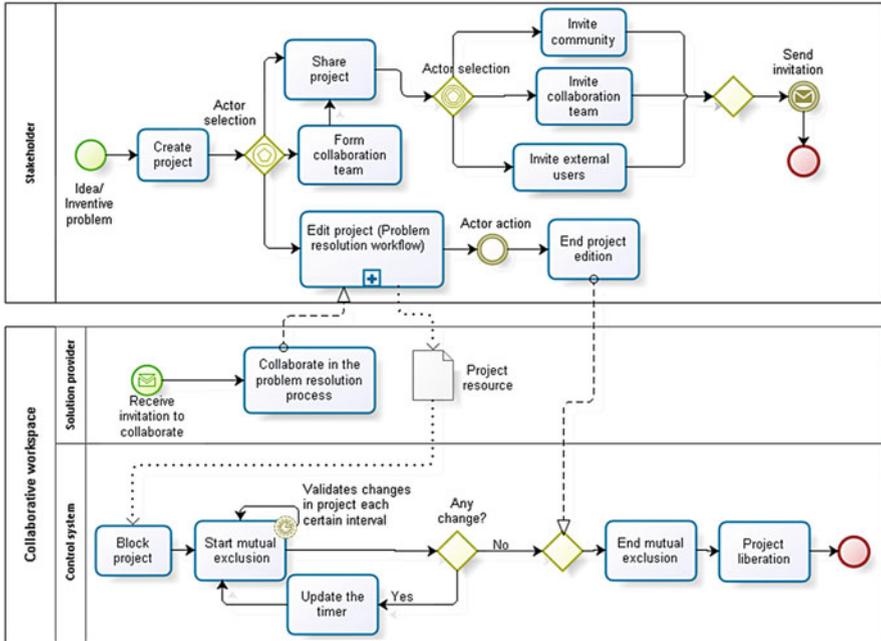


Fig. 9.8 Workflow of the collaboration service (Lopez Flores et al. 2015c)

documents, and specifies the problem background. The objective of this first step is to provide as much information as possible to describe and analyze the problematic situation. In the following steps, the stakeholder and solution providers deploy the problem resolution process as explained in the innovation process. It is worth mentioning that the way users declare all the information is via dialog forms, most of the theme composed of free-text inputs. Free-text dialogs are a common way to communicate with social network services, since they give users the means to express in the imprecise first stage of conceptual design.

9.3.2.3 Implications of Collective Intelligence

The evolution of innovation, from an idea to production and marketing, requires the participation of different intelligences. Around an idea that seems innovative, it requires an organization to aggregate collective intelligence to complete, improve, and implement such an idea (Christofol et al. 2004). Collective intelligence has existed since humans started to bring together intellectual efforts to fulfill specific tasks. Nowadays, industries have begun to focus on immaterial elements to define the firm value (i.e., brand portfolio, collective intelligence). 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. The purpose of

collective intelligence is not only to store and share the specific knowledge of team members but especially to bring new knowledge from the collaboration between different fields of expertise. Collective intelligence is not limited to sharing knowledge; it seeks to create new ones which are more demanding. This synergy is important in new product development to reduce the time to market and to improve the possibilities of a product's success.

9.3.3 Techniques for User-Generated Content

The emergence of the Web 2.0 platform allows studying the intelligence derived from groups of individuals doing things together through Web applications (Leimeister 2010). It is acknowledged that relying on the sharing and cooperation architecture provided by the Web 2.0 technologies, it is feasible to deploy applications using collective intelligence capabilities. In the architecture of participation of social network services, it is possible to combine the user-generated content with sophisticated algorithms to exploit explicit and implicit information in Web-based applications. By combining user-generated content with such algorithms, the applications improve their performance as more users take part. The techniques included to enhance these applications taking benefit from the collective contribution are tag integration, user profile, harness external content, and review.

9.4 Application Scenario

The application scenario deals with a case study focused on the conversion of biomass into energy through thermochemical processes, particularly the gasification process. The description of the problem and the constitution of the community of experts are depicted in Lopez Flores et al. (2015a). This section analyzes the problem formulation and the solution selection.

9.4.1 Problem Analysis and Formulation

After the composition of the community, the next step is to deploy the resolution process. In this part, the process is detailed, presenting the crucial phases and subphases. The attention is focused on the input data necessary for the resolution and the description of the retained idea.

The methods and tools developed in Sect. 9.3 about the innovation process afford to have a deeper and detailed analysis of the problematic situation. For the implementation, problem features are necessary as input information for the problem resolution; such features are classified as project details, problem description,

Table 9.3 Project details

Project name	Conceptual design for a fluidized bed gasifier
Nature of the problem	This project is about the conceptual design of a circulating fluidized bed process to improve heat recovery and to facilitate the operation with biomass moisture >20%
User-generated tags	Fluidized bed, gasifier, heat recovery, moisture, and biomass
System-generated tags	Fluidized bed, fluidized bed process, combustion chamber, gasification chamber, and biomass gasification

Table 9.4 Problem description

Problem statement	<p>The circulating fluidized bed process is composed of a gasification chamber, a combustion chamber, an upper and lower stream between both chambers, an outlet stream in the combustion chamber to withdraw the combustion gases, and an outlet stream in the gasification chamber for the produced syngas. The dried biomass is fed in the lower part of the gasification chamber and then flows to the combustion chamber. In the combustion chamber, gases produced by pyrolysis react with oxygen to produce CO₂ and H₂O with an exothermic reaction. This energy is transferred (through the upper stream) in the gasification chamber where the biomass is converted into solid residues (char), and the previous compounds react to produce syngas and tars with an endothermic reaction</p> <p>The three major drawbacks of circulating fluidized bed reactors for biomass gasification are: (i) the production of ashes and tars in the outflow syngas, (ii) low heat recovery, and (iii) difficulty to operate with different biomass moistures</p>
What is the name of the technical system in which the problem resides?	Circulating fluidized bed process
Describe the main useful function of the technical system	Biomass gasification
What is the impact or cost of not solving the problem?	Low energy efficiency
What are the success criteria to consider the problem is solved?	A gasifier increasing energy efficiency and using the same device to a wide range of biomass without increasing the energy consumption (in the pretreatment stage)
What are the limitations and the requirement?	<p>Temperature in the combustion chamber cannot be more than 1000 °C</p> <p>Drying chamber operation does not exceed 150 °C to avoid the risk of ignition of the biomass</p>

problem type, resources analysis, and problem formulation. To illustrate the input information, the following tables (Tables 9.3, 9.4, 9.5, 9.6, and 9.7) present the information related to the application scenario.

Table 9.5 Problem type

Failure mode common to	Machine
Specific failure mode	Fluidized bed gasifier
Problem type	Improvement

Table 9.6 Resources analysis

Resources	<ul style="list-style-type: none"> • Material <ul style="list-style-type: none"> – Gas, etc. • Energy <ul style="list-style-type: none"> – Translational energy – Heat rate – Temperature, etc.
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Table 9.7 Problem formulation

Positive characteristic	Negative characteristic	Associated parameters
17 Temperature	39 Productivity	15 Dynamics 28 Mechanics substitution 35 Parameter changes
20 Use of energy by stationary object	39 Productivity	1 Segmentation 6 Universality
22 Loss of energy	17 Temperature	19 Periodic action 38 Strong oxidants 7 Nested doll
39 Productivity	33 Ease of operation	1 Segmentation 28 Mechanics substitution 7 Nested doll 10 Preliminary action
22 Loss of energy	36 Device complexity	7 Nested doll 23 Feedback

Through the process, details about problem description, analysis, problem formulation, and solution documentation are documented in graphic user interfaces (GUIs) as shown in Fig. 9.9.

9.4.2 Solution Selection

Several ideas were generated, but only the one which was selected is presented here. This concept was chosen with the opinion that the community members expressed in a numerical way, i.e., rating, which is also useful as an input to the algorithms for a recommendation system. A collective restitution of the assessment with a ranking is made by the community members. Obviously, the potential flaw is the self-judgment bias, i.e., an individual can be inclined to give a higher score to their idea during the evaluation stage.

HOME OPEN INNOVATION PROFILE ABOUT TRIZ YOUR OPINION

COLLABORATION
 Accept Reject Collaborate

Project
 Irish coffee
 Spray drying

UPDATES:
 Latest updates

User: rene lopez
 Project: Conceptual design for a fluidized bed gasifier
 Description: Project edited
 2015-05-29 11:01:55.0

User: rene lopez
 Project: Conceptual design for a fluidized bed gasifier
 Description: Project edited

If you don't save changes or switching between tabs, the edition will end 10 minutes later

General Resolution process Assistant

Project information Problem Description Images and media Comments

In this section the objective

Problem statement

What is the name of the technical system or technical process in which the problem resides?

Describe the main useful function of the technical system or technical process

What is the impact or cost of not solving the problem?

What is the success criteria, to consider the problem is solved?

The circulating fluidized bed process is composed of a gasification chamber, a combustion chamber, an upper lower stream between both chambers, and outlet stream in the combustion chamber to withdraw the combustic gases, and an outlet stream in the gasification chamber for the produced syngas. The dried biomass is fed in lower part of the gasification chamber and then flows to the combustion chamber in the combustion chamber

circulating fluidized bed process

Biomass gasification

low energy efficiency

A gasifier: increasing energy efficiency, and using the same device to a wide range of biomass without increas energy consumption (in the pretreatment stage)

Save

Fig. 9.9 Problem description GUI

Regarding the case study, a two-round process was used to extract the most promising idea, with a cross-evaluation for each round. After the first round, the first three ideas were retained and were studied in more detail by the community members to ensure their pertinence and feasibility. With this additional information for each idea, the second cross-evaluation provides the second ranking, and this is the first idea that was chosen and is detailed below.

When the resolution process was deployed, the TRIZ principle number 7, “nested doll,” which is based on the geometrical effect “put a system inside another,” is one of the preferential solutions to explore for transforming it into a concrete concept. The first direction explored was to increase heat exchange by increasing the gas residence time in the combustion chamber. However, this leads to an increase in the size of the apparatus, which is not in line with the current trend of process intensification. Furthermore, this configuration has two major drawbacks: the enhancement of the size of the combustion chamber increased thermal losses, and the more the residence time is increased, the more the energy flux toward the gasification chamber is reduced.

To proceed further with the research of the solution, the TRIZ-CBR tool is used. After the retrieving step and relying on the previous problem description (objectives, contradictions, and resources), the case-based reasoning system extracts several devices from the knowledge base with the recommended order of use: heat exchanger coil, dividing wall column (classic, extractive, or reactive column), and heat exchanger. The common denominator between all these devices is that they are all feasible technological ways for saving energy with a reduced capital investment. The exchanger coil is not a relevant solution as a similar system is already implemented with the solid grain media for heat recovery. Concerning the dividing wall column, it is a concrete application of process intensification for a

better heat integration. It is a special column obtained by including a vertical wall inside the column shell.

Based on the combination of the TRIZ principle 7 and the concept of the dividing wall column, the following solution can be proposed: the combustion chamber could be inside the gasification chamber to reach a high exchange surface and thus increase the thermal transfer. Always with the purpose of heat integration, the gasification chamber could be situated within the storage enclosure to value the external thermal losses and to dry the biomass before to gasification to reach the 20% moisture content. However, we must account for the temperature constraint of 150 °C. Due to the high temperature of the gasification chamber compared to the desired temperature, an insulation layer should be applied to it. As a result, the proposed device is similar to nested dolls, with successive overlapping of the different chambers. Figure 9.10 presents the elements related to the conceptual solution for a new fluidized bed gasifier.

Nevertheless, in a traditional gasifier, the hydrodynamic and thermal behaviors and the produced gas are closely related to the first reaction that occurs when the biomass is fed into the fluidized bed: devolatilization. Consequently, for the proposed device, a detailed design must be done to characterize the new hydrodynamic and thermal conditions and their consequences on the transfer coefficients and thus on the conversion. It is crucial as the devolatilization phenomenon has a strong influence on the local hydrodynamics of the fluidized bed.

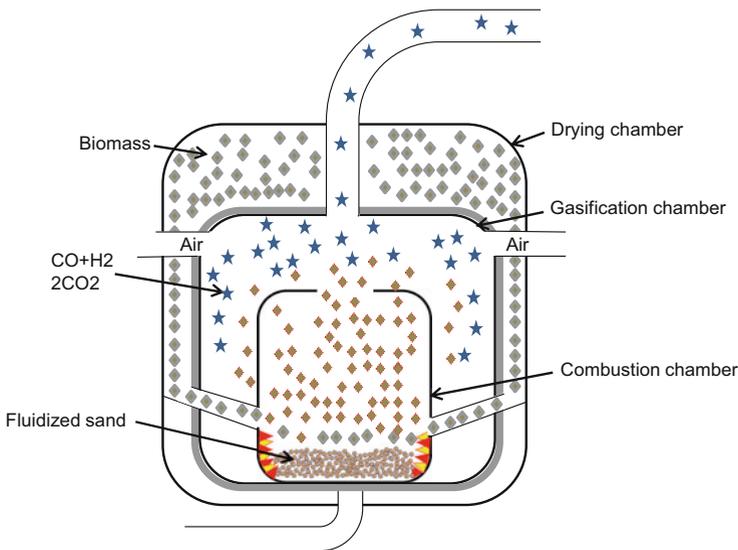


Fig. 9.10 Nested doll gasifier

9.5 Trends and Future Research

Although there are different opinions about the diversification and the future of CAI tools, they all converge in the idea that these kinds of tools are evolving through the adoption of newer technologies and techniques in the information technology field like Web technologies, virtualization, and knowledge representation, among others. These new trends are explored in this section.

9.5.1 *Ontology-Based CAI*

Knowledge extraction and representation, in the context of TRIZ, are explored to improve the capacities of CAI tools to assist in the process of innovative design. Souili et al. (2015) state that knowledge extraction from technological knowledge documents (e.g., patents) is important to boost innovation performance, while Yan et al. (2014) discuss the usefulness of ontologies for the development of TRIZ-based tools. The ontology presented by the previous authors aims to be a domain ontology of TRIZ, in specifying its basic notions for operating inventive design. Their ontology also aims to ensure that experts have a common understanding of those notions. Despite the fact that the authors try to formalize the theory's main concepts and compile partially the vocabulary that is used by TRIZ experts, the ontology is anchored to a specific resolution methodology OTSM-TRIZ (Khomeenko et al. 2007). This is an inconvenience because the ontology should remain as abstract as possible to be used in different contexts.

Li et al. (2015) argue that the indexation of different knowledge sources to solve inventive problems is promoting the development of CAI systems including ontology-based models; these types of systems combine TRIZ with various computer technologies such as text mining or natural language processing. For example, Prickett and Aparicio (2012) propose the design and development of a TRIZ technical system ontology for indexing knowledge contained within available resources (e.g., patent database). The objective of the proposed ontology is to incorporate a Web-based information retrieval system in the problem-solving process. For these authors, the development of ontologies integrated with natural language processing and artificial intelligence allows having Web agents with an analysis capacity close to humans.

On the other hand, the use of semantic technologies is explored in Yan et al. (2014) to formalize the main concepts in the TRIZ knowledge sources through an ontology. The previous authors intend to build an "intelligent manager" system based on short-text semantic similarity and ontologies. Short-text semantic similarity defines missing links among TRIZ knowledge sources, and the solutions are obtained through ontology reasoning. The objective of the proposed systems is to reach more accurately defined solution models.

9.5.2 Avatar-Based Innovation

Traditionally in the market-pull strategy for innovation, manufacturers start exploring user needs and then develop products to fulfill the requirements; nevertheless, this activity is complex, time consuming, and expensive. Moreover, the approach shows its limitations when the user needs change rapidly. Von Hippel and Katz (2002) propose the use of toolkits as an emerging alternative to understand user needs in detail. As a design tool, toolkits transfer *need-related* aspects of new products or services to users. On the other hand, a more interactive approach to address this problem is found in the emerging technology of virtual worlds.

Virtual worlds offer new possibilities for enhancing innovation activities through virtual customer integration. The use of virtual worlds for real-world innovation is explored in Kohler et al. (2011) with the concept of avatar-based innovation. Avatar-based innovation provides a digital environment conducive to develop open innovation and creative tasks. The authors demonstrated how virtual worlds deploy an open innovation platform, which allows producers and customers to swarm together with like-minded individuals not only to create new products but also to find an audience to test, use, and provide feedback about those creations. The previous authors formulated two questions in order to understand the potential of virtual worlds for real-life innovation:

- How are virtual worlds different from the two-dimensional Web and the real world?
- What opportunities arise from this difference?

Avatar-based innovation offers a new medium to understand the user needs through virtual customer integration in an open innovation process. Using this approach, companies can enhance their innovation efforts by learning how to engage and co-create with avatars (the latest visual representation of their potential customers).

9.6 Conclusion

The initial motivation for this research work is to contribute to the evolution of CAI tools to the next evolutionary step named Open CAI 2.0. We studied recent advances on innovation management paradigms as well as the implication of Web 2.0 as a technological driver for collaboration. Also, we addressed some problems related to the systematizing of creativity in inventive problem solving. The use of collective intelligence in combination with the TRIZ-CBR model was proposed to improve the capacity of a community to develop, evaluate, and select a solution for inventive problems.

The first contribution of this work was to understand the mechanism related to the innovation process, specifically when it happens in collaboration. The research

approached to the open innovation paradigm, which is a model that promotes the active participation of internal as well as external actors to the enterprise boundaries. Moreover, it valorizes internally generated knowledge through different channels, and it promotes the integration of external knowledge sources in the innovation process.

With the increasing amount of information and the challenge to coordinate participants located in different geographical areas, it becomes necessary to have adapted computational tools to assist the different activities. One technology widely implemented and widely accepted in the industry is the Web platform. Specifically, Web 2.0 as a platform for collaboration has multiple advantages, such as the following:

- Not an expensive technology.
- Supporting different collaboration patterns.
- Accessible from different locations and different devices.
- Employees are familiarized.

After the study of the innovation mechanism and collaboration technologies, the second contribution was to analyze existing tools related to the field of CAI. It was observed that current trends in the CAI field are related to the use of collective intelligence (i.e., crowdsourcing services) for the implementation of open innovation practices.

The third contribution was to propose a collaboration architecture for TRIZ-based Open CAI 2.0. The functional aspects were introduced. The framework is organized according to three core levels. The lower one concerns the Innovation process and it is mainly focused on ideas generation and selection. To manage the large amount of knowledge deployed in open innovation while continuing to generate rapidly innovative ideas we have developed a dedicated methodology based on TRIZ and Case Based Reasoning. The intermediary level is focused on the collaboration and the way to create a collaborative environment to facilitate knowledge exchange. This is done by taking advantage of the benefits of on line Social Network. Finally the last level is dedicated to the Collective intelligence, i.e. human creative effort in community in combination with the power of computer algorithms.

Finally, our findings suggest that it is necessary to overcome several barriers to achieving a real collaborative innovation in an open context. In this chapter, 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 expose the possibilities to improve participant's creativity in the innovation process.

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