ICED13
INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED13
19-22 AUGUST 2013, SUNGKYUNKWAN UNIVERSITY, SEOUL, KOREA

IMPLEMENTING COLLABORATIVE CROWDSOURCING IN DIFFERENT DESIGN PROBLEMS

Donata GABELLONI, Gabriele MONTELISCIANI, Gualtiero FANTONI
University of Pisa, Italy

ABSTRACT

The new product development process increasingly involves multidisciplinary teams, that frequently do not belong to the same institution. Innovation often comes from external actors, as suppliers, end-users etc., according to the paradigm of Open Innovation. Crowdsourcing is one of the new trends in the Open Innovation philosophy. The main aim of this study is to present how and for which design activities crowdsourcing is useful for the new product design.
After a brief definition of benefits and limitations of collaborative crowdsourcing, the paper presents a new web platform that allows the collaborative design of new products. The main features of the platform are tools suitable to overcome some of the presented criticalities of crowdsourcing, such as an IPR tracking system. These tests have been used to evaluate the developed tools, as well as to identify the typologies of product design problems that can be advantageously solved through crowdsourcing. For each class of problems some guidelines to manage the problem solving sessions are provided.

Keywords: crowdsourcing, open innovation, collaborative design, new product development

Contact:
Donata Gabelloni
University of Pisa
Department of Civil and Industrial Engineering
Pisa
56122
Italy
d.gabelloni@gmail.com

1 INTRODUCTION

The product design process is a complex activity that generally takes advantages from the collaboration of a group of designers. A design team has to overcome several critical issues, such as the coordination problem, but especially knowledge sharing and communication (Dong, 2005). Furthermore, the more the team is multidisciplinary the more the project can benefit from such variety, especially in the early phases of the design process, when alternative technologies and solutions are chosen. The diversity can help the creative process by providing team with heterogeneous perspectives (Kurtzberg, 2005).

In recent years a growing interest in the involvement of external actors in new product development process emerged. The open innovation paradigm shows how external sources of innovation are critical when designing new products (Chesbrough, 2003). According to Chesbrough (2003; 2006), Open Innovation entails two types of knowledge flows: (i) Inside-out knowledge flows, corresponding to knowledge developed within the firm and made accessible to other firms and (ii) Outside-in flows, corresponding to knowledge developed in the environment and being integrated by the firm. Suppliers, end users, designers of other companies and other external actors can be sources of innovation for a company. For example Terwiesch and Ulrich (2009) noted that across industries about a quarter of innovation opportunities tend to come from interactions with customer requirements. Usually users input can come in two forms: as a market research on users' needs or as a solution-based information on a specific problem (Marion et al., 2012). Today, user-centered innovation demonstrated to be a very powerful and general phenomenon (von Hippel, 2005).

More broadly, some theories support the importance of the involvement of the crowd for the problem solving activity. Surowiecki (2004) examines several cases of crowd wisdom at work, where the success of a solution is dependent on its emergence from a large body of solvers. Basing on these empirical investigations, Surowiecki (2004) claims that "under the right circumstances, groups are remarkably intelligent, and are often smarter than the smartest people in them".

As a consequence, one way to exploit the wisdom of the crowd (including users, supplier, etc.) is the paradigm of crowdsourcing. Howe (2006), who coined the term crowdsourcing, defines it as "the act of a company or institution taking a function once performed by employees and outsourcing it to an undefined (and generally large) network of people in the form of an open call. This can take the form of peer-production (when the job is performed collaboratively), but is also often undertaken by sole individuals. The crucial prerequisite is the use of the open call format and the large network of potential laborers"(Howe 2006).

Crowdsourcing can be very useful in some phases of the new product development process. However not all design problems can be solved through this approach due to many limits, most of which directly emerged from the analysis of existing crowdsourcing platforms.

The main goal of this study is to propose **which kind of product design problems can be solved through this emergent approach.**

First paragraphs will thus outline the main features of crowdsourcing in terms of benefits for the design process. This is followed by the presentation of a self-developed crowdsourcing platform that presents particular and unique tools for motivating solvers participation. Then, the analysis of three collaborative discussions will delineate problem classes that best fit with collaborative crowdsourcing platforms. Finally, basic guidelines for the conduction of different problem solving session typologies will be provided.

2 STATE OF THE ART

Crowdsourcing is a new approach based on the open innovation paradigm. It can be used for several purposes such as graphical design, data analysis, or simple tasks as the digitalization of an archive (Schenk et al., 2009). New product development is also performed by crowdsourcing platforms. *Innocentive*, *Nine Sigma*, *Atizo* are examples of such platforms, where companies submit a design problem and the solvers of the crowd try to find the solution, in order to get the rewards (Feller et al. 2012). The usage of this platform allows the designers to exploit competences and expertises which are distributed among a worldwide crowd. Generally the existing crowdsourcing platforms provide an environment where the solvers can post their solution, like a web forum, and occasionally with some particular tools to stimulate creativity or share files. However there are not specific tools suitable for the engineering design process, such as tools for sketching, CAD modules, etc..

In the management research field several works show the business models to adopt crowdsourcing. Some papers describe several examples of the application of the crowdsourcing approach (Frey et al., 2011; Brabham, 2008; Feller et al., 2012) and specify which kind of collaboration is right for a specific problem (for example open vs close approach) (Pisano and Verganti, 2008). On the other hand they do not provide guidelines to understand which design problem can be solved through crowdsourcing and which specific methods are most suitable to obtain an effective and efficient design. Crowdsourcing has also some limitations and criticalities (Schenk, 2009). One of the most critical issue is the protection of the intellectual property (IP) of the designer, as generally crowdsourcing platforms do not protect the IP of the participants. Sometimes platforms subscription agreements include the inability of the participant to claim the IP. In other cases they require the winners to transfer the IP to the platform. Up to now the adopted solutions have not satisfied the solvers yet. Thus solvers can be less motivated to contribute to the problem solving sessions. Furthermore solvers have realized the usefulness and indeed the necessity of an appropriate way of tracking each participant's contribution and of sharing the profits accordingly. Past experience shown evidence that the protection of Intellectual Property Rights boosts motivation, trust and participation in every Open Innovation environment (Fantoni et al., 2009).

Designing through crowdsourcing often entails collaboration between people with different backgrounds, different expectations and from different geographical areas. Thus the management of heterogeneous teams should pay attention to several critical aspects such as the roles and relationships within the team, their planning of the design process, their gathering and sharing of information, their ways of analyzing and understanding the design problem, their ways of developing and adopting design concepts, or their resolution and avoidance of conflicts (Cross et al., 1995). Several works analyze how to manage the design teams and which kind of tools can be useful to ease the design process. Wang (2001) outlines the methodologies, architectures and tools based on internet and web technologies to design new products.

Various research projects allowed the development of product design tools for exchanging information during shared problems (Biehl, et al. 2008; Erickson et al., 2000; Lee, 2006; Oehlberg et al., 2011). A growing number of studies on teamwork and coordination processes is appearing in the context of Computer Supported Cooperative Work (CSCW) (Grudin, 1994; Shen et al., 2008). CSCW studies focus on the interdisciplinary study of coordination (Malone et al., 2004) and allow the researchers to design cooperative work tools and distributed and parallel computer system. The Mechanical Engineering Department at Stanford has been observing engineers working in design teams (Leifer, 1998, Atman et al., 1999, Cannon et al. 1997). They create Web-based services to enhance peer-to-peer communications, cogeneration, and sharing of design knowledge (Leifer et al., 2004).

The presented literature shows how complex is the design and the management of the design teamwork and which kind of features collaborative crowdsourcing tools should have. Most of the above-mentioned tools provide environments where the designer can collaborate and share knowledge. However these instruments are generally addressed to team composed by stable members of a company, paid to perform the particular task. Therefore these works neglect which kind of tools are more suitable to attract the participants and to maintain solvers’ motivation during the time. This is a critical issue in the crowdsourcing approach that is based on the work of people who are not direct employees of the company (Fantoni et al., 2012).

3 A NEW COLLABORATIVE CROWDSOURCING PLATFORM

In order to assess the performance of collaborative teams in challenging different types of problem solving sessions, a collaborative crowdsourcing platform has been used. The platform is a comprehensive environment for innovation and collaborative problem solving, self-developed by University of Pisa *Leaning Lab*, partner of The European Network of Living Labs (http://www.openlivinglabs.eu/). Various problem solving challenges, experienced by *Leaning Lab* in last decade, permitted the definition of clear requisites to be fulfilled by the platform. Main features are therefore the following (Fantoni et al., 2012):

- a dedicated software platform allowing participants to interact each other, according to the "open innovation" paradigm, in the productive activities and in the process of product and service development;
- a set of technologies and innovative tools aimed at favoring motivation and creative participation among users, such as:
  - crowdsourcing applications and intellectual property right (IPR) tracking systems;
  - a search engine that in turn searches within three major search engines (Google, Wikipedia and Freepatents) the most relevant results related to the post content. It is a dynamic learning environment that provides a series of visual and ideal cues to boost imagination and suggests new uncharted horizons (Apreda et al., 2012).
- problem solving and concept design technologies (based on the findings obtained from the scientific research in the field of functional design) supporting and driving users creativity in order to engender systemic innovation;
- a Team Builder, that analyzes problems content and selects best solvers from the community, basing on skills and problem solving attitudes of each individual (Tazzini et al., 2013);
- product and process innovation laboratories (the new "Living Labs") in different industry districts.

A platform where users could be paid if they solve a problem is a great catalyst of users (Fantoni et al., 2012). Thus, a notable feature of the platform, among the others, is the mentioned IPR Tracking System (Fantoni et al., 2009): a set of algorithms based on Natural Language Processing (NLP) that track and quantify the percentage contribution of each solver to the final solution. This allows fairness of the reward and protection of ideas, boosting motivation, trust and participation. *Leaning Lab* community concerns experts from different institutions, such as University of Pisa, Sant'Anna School, Scuola Normale Superiore and firms from many sectors (automotive, bio-medical, robotics, industrial tools). A functioning scheme of the platform is reported in Figure 1.
In essence, the process starts when a seeker proposes and defines a technical discussion. Once a particular problem is stated and the Team Builder identifies the most suitable team, selected individuals decide to grant a little part of their time to join the session, as nobody is regularly full-time involved in the platform. Therefore, the presence of effective tools for facilitating solvers participation and guaranteeing objective and fair rewards are key elements of success, as well as tangible distinguishing features from other collaborative design platforms. Once the session has ended with a positive solution, the IPR tracking system quantifies the intellectual contribution that each solver gave to reach the goal. Rewarding and successive updated of solvers' profiles are based on the previous calculation.

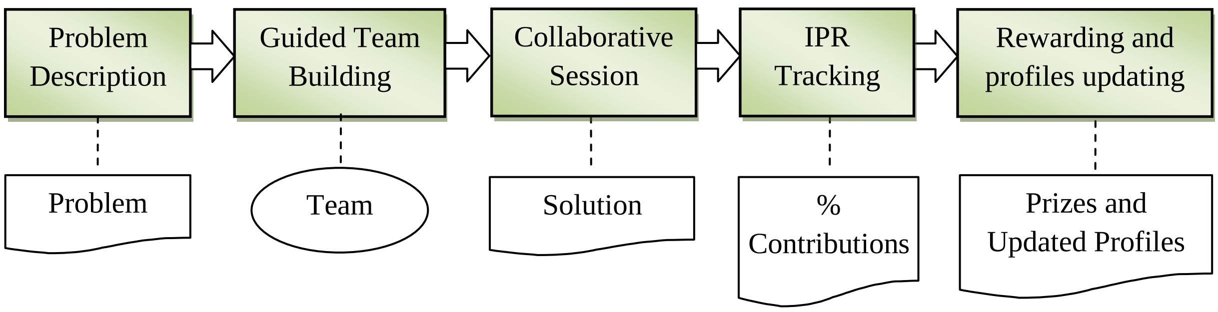

Figure 1. Leaning Lab Platform Functioning Scheme

4 CASE STUDY

Leaning Lab collaborative design platform has been tested with several design problems in the field of industrial pumps, sport tools, industrial brushes, food industry, etc. Such experience highlighted the need for a detailed investigation of design problems typologies, and what are the most suitable for a collaborative software. Three problem solving sessions have been delineated. Problems have been classified according to Fantoni et al. (2006), that defined four main problem classes (Figure 2) that imply different configurations of the solvers' team, as well as of the problem solving method. In particular, the four classes are:

A. **Incremental** innovations on **actual** generation of **a** product, such as, for example, engineering problems, where a robust discipline forms the background, and known and reliable methods exist.
B. **Incremental** innovations on an entire class of **actual** products. When a new class of products has to be redesigned a systematic approach is fundamental and structured collaborative problem solving techniques can be used in order to investigate the product class from its general aspects to its details.
C. **New** architecture for the **next** generation of product**s**. A new structure/concept is requested; a "quantum leap" in the improvement is expected. It is possible to expect stepping innovation and interesting breakthroughs in comparison with the past solutions (usually unstructured brainstorming is the method used). This class of problems needs teamwork where collaboration is highly encouraged and multidisciplinary teams are preferred. An unstructured brainstorming, is suggested: the multidisciplinary team solves the problem using standard brainstorming rules while the innovation manager guides the discussion and filters the proposal.
D. Next generation of **needs** within a field. Totally new breakthroughs are expected, a low number of constraints is usually imposed by an existing architecture, the aim of these problem solving is to overcome the existing architecture. The problem is not defined at the beginning and only by the research of solutions it becomes clear in time. Without collaboration no solution can be expected. Dis-alignment of skills is not wished but necessary.

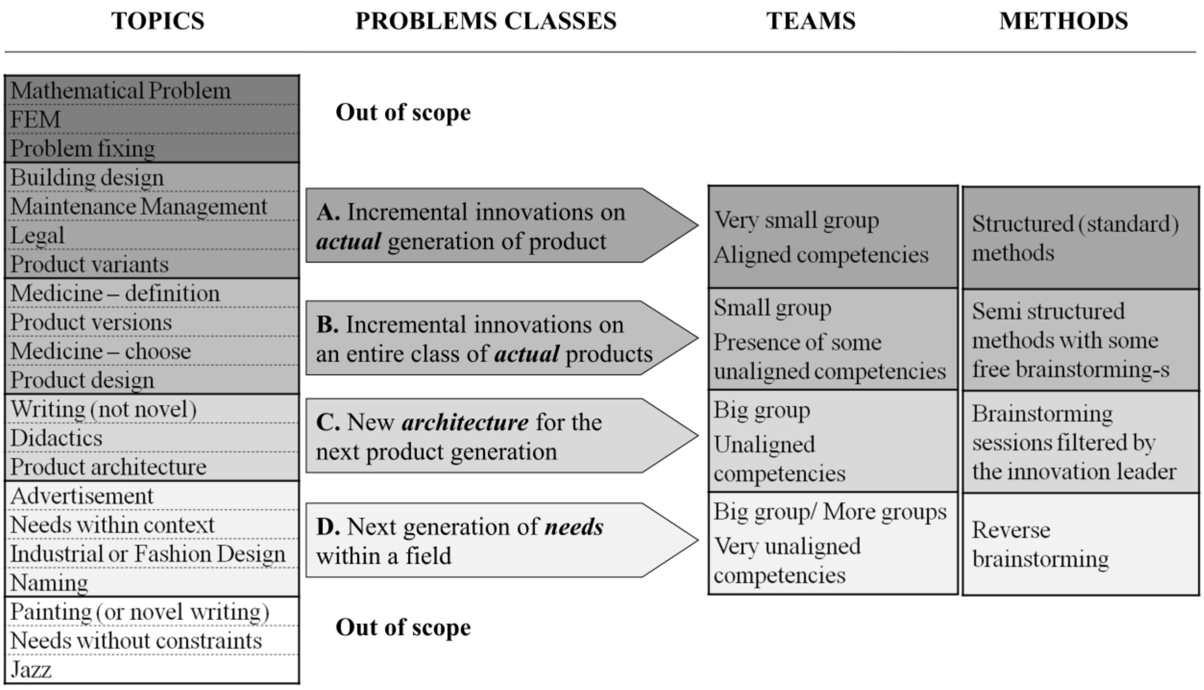

Figure 2. Problem classes and relative problem solving teams and methods for their solution (Fantoni et al.,2006).

With reference to the reported classification, the three problems submitted in *Leaning Lab* platform to three different teams are described in Table 1. No problems belonging to class "A" have been considered in this research since past initiatives demonstrated that collaborative sessions on structured incremental innovations involving very small groups present several limits (see next paragraph).
On the contrary, the following **sessions topics** have been chosen. The first challenge is the definition of a new concept of industrial gripper following particular constraints and requirements, and refers to problem class "B". The second challenge, class "C", refers to the identification of new systems and methods for enhancing alimentary products background information, as well as, food companies transparency. The last challenge, class "D", concerns the identification of new fields of application of an human android originally conceived for autism rehabilitation (F.A.C.E., Facial Automation for Conveying Emotions).
The **teams** have been built according to the problem content, participants belonging to the *Leaning Lab* community have been involved. Basing on problems statements, tailored NLP based algorithms identified the individuals whose profiles have the best match with the problem. As reported in Table 1

and according to the main characteristics of problem classes (Figure 2), the sessions have been designed as follows (from problem 1 to 3):

- problem solving teams presented an increasing number of components,
- skills heterogeneity has been widened,
- the session duration has been increased.

Some results were easy to be foreseen: the longer the session duration the higher the number of contributions. In fact, the “Gripper” session class B required 4 days and obtained 19 contributions, the “Products life” class C session required 7 days and 30 contributions, while “F.A.C.E.” class D has been 17 days long with 52 contributions. However the number of contributions is not depending only on the duration of the session, as described in next paragraph. **Moderators** contributed to sessions success with different efforts. The number of interventions in each discussion, expressed in Table 1 in absolute and percentage values in respect to total contributions, gives a clear indication of the different methods used to manage the single discussions, as described in next paragraph.

Table 1. Problem solving sessions: description and statistics

Problem Title	**1. Gripper for deformable thin objects handling**	**2. Can we look into products' life?**	**3. F.A.C.E. (Facial Automaton for Conveying Emotions)**
Class (Fantoni et al., 2006)	B. Incremental innovation on an entire class of actual products	C. New Architecture for the next product generation	D. Next generation of needs within a field
Purpose	Delineate a new concept of industrial gripper basing on precise technical requirements.	Identify strategies to raise food-companies transparency, honesty, as well as customers fidelization.	Discover new fields of application of an human android able to perform several different facial expressions.
Tasks	To define an on-demand switchable adhesion technology that can rapidly pick up objects on one side, transport these and fast release them by reversing the adhesion/gripping effect.	To define: - Who is the target consumer; - What kind of product is more suitable with the "investigation"; - How: specify means of collection, elaboration and communication to consumers.	To define the field of application and to indicate for which specific tasks the android could be used.
Teams size	6 solvers	8 solvers	13 solvers
Solvers skills	Mechanics; Materials science; Robotics	Management; Mechanics; Electronics; Logistics; Marketing	Management; Mechanics; Electronics; Logistics; Bio-Engineering; Innovation; Marketing; Comp. Science
Session duration	4 days	7 days	17 days
Solvers contributions	19	30	52
Mean number of contributions per user	3	3,7	4
Moderator interventions (%)	20 (51%)	7 (19%)	5 (9%)
IPR Tracking results	$S_{1.1}$ (47%); $S_{1.2}$ (26%); $S_{1.3}$ (22%); $S_{1.4}$ (6%); $S_{1.5}$ (0%); $S_{1.6}$ (0%).	$S_{2.1}$ (45%); $S_{2.2}$ (22%); $S_{2.3}$ (15%); $S_{2.4}$ (10%); $S_{2.5}$ (5%); $S_{2.6}$ (3%); $S_{2.7}$ (0%); $S_{2.8}$ (0%).	$S_{3.1}$ (25%); $S_{3.2}$ (17%); $S_{3.3}$ (13%); $S_{3.4}$ (11%);$S_{3.5}$(11%); $S_{3.6}$ (7%);$S_{3.7}$ (4%); $S_{3.8}$(3%); $S_{3.9}$ (3%); $S_{3.10}$ (3%);$S_{3.11}$ (2%); $S_{3.12}$ (1%); $S_{3.13}$ (1%)

For what concerns the **IPR tracking** feature, results are synthetically reported in Table 1, where solvers are ranked from higher to lower contribution to the final solution. For each session, each solver participating at session *m* and ranked at position *n* is indicated as $S_{m.n}$. With reference to the first problem solving session, solver $S_{1.1}$ reached the first position giving the 47% of contribution to the final solution. The IPR tracking result for problem 3 derives from the combination of solvers contributions to three different solutions emerged from the brainstorming. Each solver obtained three percentage values, opportunely summed and normalized to 100% in order to quantify the overall contribution to the selected solutions, as shown in Table 1. In the following section an interpretation of the data collected during the problem solving sessions, will be provided.

5 FINDINGS

Many evidences emerged from the presented tests, confirming the theoretical framework used as reference. In addition, sessions results demonstrate the effectiveness of collaborative crowdsourcing platforms for particular classes of innovation problems. Data reported in previous paragraph will be interpreted and commented in order to identify pros and cons of the use of collaborative platforms for different classes of problems.

Firstly, it can be noticed that team size and composition vary according to problem typology. As reported in Figure 2, in fact, effective incremental innovations require smaller teams than new products architectures and, even more, the identification of new generations of needs. Moreover, the 6 components of the first problem solving team were aligned on few homogeneous skills (Mechanics, Materials science, Robotics), necessary to solve a very delineated technical problem. Technical background of the 8 members that joined the second problem solving session was instead more various. A discussion about a concept of new product architecture requires in fact an higher number of disciplines, 5 in this particular case, concerning a broader field of knowledge (Management, Mechanics, Electronics, Logistics, Marketing). For what concerns the third problem solving session, the 13 components covered at least 8 main disciplines (Management, Mechanics, Electronics, Logistics, Bio-Engineering, Innovation, Marketing, Computer Science), as strongly heterogeneous expertise is required for identifying future solutions to fulfill both technical and market needs within a particular field. The beta version of the *Team Builder* feature in *Leaning Lab* platform permitted an easy identification of community users that matched some competencies (Tazzini et al., 2013). Users profiles, in fact, are composed of information related to explicit skills, declared by each individual and verified measuring the real capacity to contribute to the solution of a problem in that particular topic. In addition, natural language processing algorithms allows the identification of the so-called *hidden knowledge*, i.e. individual hidden capabilities that comes out after a single discussion and that enrich solver's profile. Also data about sessions duration are aligned to related theoretical framework. The technical discussion about the industrial gripper required only 4 days to delineate and select an effective solution. Such efficiency is due to several factor such as narrower field of discussion and a clearer definition of final goal and technical constraints.

The high number of moderator interventions, on the other hand, can be interpreted in this case in a less rigorous way. Although a well defined session should require few moderations, actually the moderator tends to over intervene, trying to add more selection criteria in order to increasingly restrict the field of possible solutions. On the contrary, the F.A.C.E. android brainstorming required more than two weeks to identify relevant solutions. In general, this class of problems entails more time to define the best direction to follow, and, in addition, a low number of discussion constraints lead to more interactions between solvers, generating a high number of new ideas and topics that feed and lengthen the discussion. Such free brainstorming performed in a very early stage of the conceptual design allows to generate a high number of divergent ideas. This leads to an higher mean number of contributions per user (4 in our case) with respect to more structured problems (3), where the team acts to converge to a unitary solution after a preliminary feasibility study.

The performed tests also highlighted pros and cons that crowdsourcing collaborative conceptual design entails. Firstly, it is obvious that an h24 accessible online service allowed the asynchronous participation of solvers from different parts of the World. The opportunity of accessing to a wide community of expertise allowed to reach effective solutions making use of skill that were not present within the University research team. It should be also highlighted that, even if born from a beta test for the *Leaning Lab* Platform, the three final solutions, successively used for different real applications, demonstrate once again their practical effectiveness. Selected ideas from presented sessions have been

put into practice for the participation to a financed research call (Problem 1) and for the definition of a concrete bid to a private food company (Problem 2). An important aspect to be considered in this environments is participants motivation (Fantoni et al., 2012). *Leaning Lab* case studies demonstrate that the IPR Tracking feature, as well as initiatives for favoring community learning process, are tangible solutions to such issue. In particular, the percentages reported in Table 1 have been analyzed by experts in order to verify if linguistic engines correctly quantified the contribution of each solver to the final solution. The maximum discrepancy between IPR algorithm and experts' assessment was less than 10% and had a mean value of ±5%. Such results confirm the effectiveness of the method and guarantee the fairness and objectivity in prizes distributions.
Crowdsourcing platforms for collaborative design and problem solving present some limits. First of all the absence, at present, of graphic tools and CAD environments to reproduce the analyzed concepts by means of sketches and 3D models. For what concern *Leaning Lab* platform in particular, this aspect also collides with the IPR Tracking functioning. Engines based on natural language processing are obviously unable to measure the intellectual contribution of an individual by means of graphical features, limiting its functioning to textual contributions. In other words, images and graphical models must always be supported by textual descriptions in order to be considered as concrete contributions to the final solution. In order to summarize the results of the present research work and according to Fantoni et al. (2006) problems classification, Table 2 reports, for each problem class, their feasibility in being addressed through a crowdsourcing platforms for collaborative design and problem solving.

Table 2. Problem solving for crowdsourcing platforms: empirical evidence of problem classes characteristics and feasibility

Problems classes	Characteristics and feasibility on crowdsourcing platforms
Class A	The problems in this class **cannot** be easily addressed through crowdsourcing since very specific skills and appropriate tools are necessary. In fact, such problems are related to late stage of design, where numerous face-to-face interactions as well as advanced supporting tools, such as CAD drawings, are required.
Class B	**It is possible** to solve these problems through crowdsourcing. Problems are more technical and complex and therefore limited groups of **experts** belonging to well defined fields are preferable. Generally, prizes are higher for such problems and the solution is often the result of an evolution of ideas. For this reason, here the IPR tracking system is very useful for identifying the real contributions of the participants. On the other hand, this class may also include problems presenting extremely high technical issues and/or faced during detailed design. In this case it would be difficult to use an online platform for crowdsourcing. In these cases other supporting tools are necessary, such as collaborative CAD systems that allow the visualization and definition of products design parameters. As already said, experts join crowdsourcing initiatives in their free time only if the incentive (e.g. monetary prize) for the participation is very high.
Class C	These types of problems **can** be usefully addressed through crowdsourcing platforms. The group of designers is more **numerous** and **heterogeneous** with respect to these cases. In this case the management of the community by the **moderator**, which guides and addresses the discussion, is extremely important. Class C problems cost less in terms of intellectual and time effort in respect to class B, so that prizes and participation incentives can be lower.
Class D	In this case the collaborative crowdsourcing is very useful, since the **team** needs to be very **wide** and **heterogeneous**. Problems technical level is lower so that the solution seeker can take advantage from the contribution of people with different backgrounds. In that case there may not be a single solution, but more than a single concept satisfies the proposed problem. The IPR tracking system is therefore used on the single identified solutions and for each of them solvers to be rewarded are identified (therefore one may receive the prize for its contribution to more than one solution). This should give a strong motivation to participants to post ideas and solutions. In this case the participation is considered as a funny game to participate to and people participate more to gain credits and skills than to earn money. Prizes can be very low.

6 CONCLUSION AND FUTURE WORKS

The paper highlighted the usefulness of collaborative crowdsourcing for fostering innovation and new product development. The authors and the *Leaning Lab* research team developed a collaborative crowdsourcing platform where the presented tests have been conducted. The tests allowed the identification of the particular classes of problems that can be solved through crowdsourcing. Problems concerning less technical issues and needing very wide teams and heterogeneous expertise result to be the more suitable for collaborative crowdsourcing design sessions. According to the problem typology, guidelines to define teams size and composition, and to manage the crowdsourcing sessions have been described. Emerged criticalities related to the presented platform have been also highlighted.

The present study has only investigated some of the possible design problems, therefore further tests with different problem classes will be performed in order to better understand when crowdsourcing is actually effective. Future works will also reveal which other strategies and tools can be used to overcome the identified criticalities, in particular how to provide incentives and motivate the participants. According to the functioning of the present platform, a new set of tools are being integrated within the platform in order to improve the collaborative design. A graphical virtual environment that enhances the collaborative design experience will be a contribution toward that goal.

ACKNOWLEDGMENTS

This research work was supported by LILIT Project (PAR FAS REGIONE TOSCANA Linea di Azione 1.1.a.3) and RobLog Project (FP7 ICT-270350).

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