Crowd vs. Crowd: Large-Scale Cooperative Design through Open Team Competition

Cheong Ha Park, KyoungHee Son, Joon Hyub Lee, Seok-Hyung Bae
I^{2}DEA Lab, Department of Industrial Design, KAIST
291 Daehak-ro, Yuseong-gu, Daejeon 305-701, Republic of Korea
cheongha.park | kyounghee.son | joonhyub.lee | seokhyung.bae @kaist.ac.kr

ABSTRACT

Following the recent remarkable successes of crowdsourcing, there have been attempts to apply it to design. However a design problem is often too complex and difficult to break down into simpler, distributable tasks as required by the conventional crowdsourcing model. In this paper, we present Crowd vs. Crowd (CvC), a novel design crowdsourcing method, where several design teams made up of designers and crowd compete with each other. In each team, a designer coordinates effective communication between the crowd members and takes responsibility for the final design output, and the crowd contributes at different stages of design. We conducted an initial evaluation of CvC in comparison with other collaborative design methods, and found that: CvC can attract more people to participate; the crowd can make useful contribution in CvC; CvC can produce competent design outputs. We then applied CvC to two real-life design problems: first, designing a new logo for a university department; second, for a small tech company. With quantitative and qualitative analyses on these applications, we observed that the elements of competition and collaboration helped to sustain the crowd's motivation to participate, and to produce quality design outcomes with higher level of satisfaction for the stakeholders.

Author Keywords
Design process; crowdsourcing; competition; collaboration

ACM Classification Keywords
H.5.3 [Group and Organization Interfaces]: Collaborative computing.

General Terms
Design.

INTRODUCTION

Traditionally, industrial design processes focused on creating aesthetically pleasing products, and were conducted only by professional designers. However, industrial design has expanded to include design of systems, interfaces, services and user experiences, and newly emerging design methodologies are inviting various stakeholders including end users to take part in the design process to meet their various needs and wants. Notable open methods include: 'user centered design' that emphasizes the actual conditions and needs of users; 'participatory design' in which users equally participate as designers [11]; 'co-design' that lets users customize a design [20]; 'non-intentional design' that draws design inspirations from users' unconventional use of everyday objects [3]. Active participation of non-professionals is becoming a mainstream in design with its expanded scope.

Building on such an inclusive trend, there are attempts to crowdsource the design process itself, in the hope that a large number of non-designers will participate and collaborate to solve a design problem better than any single designer or a design team can. Crowdsourcing has been particularly effective in generating volume and diversity, and previous attempts to crowdsource design showed that large-scale crowdsourcing can be beneficial at separate stages of design process such as data collection [23], user study [12], and design evaluation [27].

However, it is more challenging to crowdsource the entire design process, as it requires analysis of the design problem, insight on the design context and integration of creative solutions at a deeper level. Such an oversight is difficult to achieve with the simple crowdsourcing model, which breaks down a problem into small pieces, distributes them, and collects and combines individual solutions mechanically. In addition, a non-designer individual without the appropriate design skills and expertise is unable to visualize, develop and finalize a design, no matter how small a piece it may be. Moreover, such a design crowdsourcing would benefit from the crowd keeping track of the design process in progress, but it is difficult to sustain the level of motivation and enthusiasm required for them to do so.

In this paper, we suggest a new method to effectively crowdsource the entire design process. We begin with the acknowledgement that designers and non-designers can contribute in different ways, and develop a way for them to effectively collaborate. In doing so, we pay special attention on different characteristics of various phases within a design process, on utilizing designers' expertise to visualize, develop and finalize a design, and also on sustaining the level of motivation of the crowd. Finally, we show that our new method can be applied to real design problems to produce satisfactory design outputs.

CSCW '13, February 23–27, 2013, San Antonio, Texas, USA.

RELATED WORK

Crowdsourcing Simple Tasks

There are many successful cases of crowdsourcing in various fields. Representative works are: 'Be a Martian' by NASA that organizes and analyzes hundreds of thousands of pictures taken from Mars [1, 10]; 'RECAPCHA' that prevents automated string input on a website by asking the user to type characters from a scanned image of a document which cannot be recognized with OCR [21]; an online game 'FoldIt' that predicts folded structures of proteins [5]; 'eBird' that watches birds through networking local volunteers [24]; and 'The Johnny Cash Project' that creates new music videos by having Johnny Cash's fans redraw still-cut frames of the original music video [26]. Online labor markets such as MTurk of Amazon reduced the cost and effort required to construct the necessary infrastructure, and inspired new crowdsourcing possibilities.

One characteristic of these cases is that they crowdsource by providing participants with micro tasks, which are easy enough for each participant to conduct for a small amount of cash or out of personal interest. Another characteristic is that a large number of partial results can be accumulated into a meaningful solution, often requiring quantity more than quality of work.

Crowdsourcing Complex and Creative Tasks

There are recent crowdsourcing projects that deal with more complex and creative tasks. Lakhani et al. claimed that modularization through task decomposition is essential in solving these tasks [17]. Early attempts relied on multitudinous trials. An example is an algorithm which asks people on MTurk to interpret badly written handwritings repeatedly until the match rate improves [18]. The focus shifted to proper distribution of tasks among crowd with a predefined format or workflow, for example, in writing an article [14], translating English text into Latin [13], and summarizing a video [25]. More recent studies explore ways for crowdsourcing operators to interactively modify the workflow based on the participation trend or feedback from the crowd [7, 15, 16].

Capturing the interests and therefore the devotion of the proper kind of crowd is also important. Heimerl et al. showed that installing a physical kiosk at the target-specific location and giving out proper reward results in high participation rate and task performance [8].

Crowdsourcing to Solve Design Problems

Design processes are increasingly conducted by a team of different experts rather than by an individual designer. This trend of expansion combined with social network infrastructure implies a possibility of large-scale crowd collaboration. Previous web-based design crowdsourcing studies involve crowd in various isolated stages of design process: data collection [23]; user research [12]; and evaluation of the final design [27].

More recently, Yu & Nickerson proposed an iterative design process of idea generation and evaluation to design a chair for children [28]. They showed that crowd can generate creative and diverse ideas through combining and mutating the previous generation of design ideas. However, their method did not produce a design output at the level of quality required for real-life application. We think that this is due to the fact that their non-designer crowd lacked the necessary design skills and expertise such as graphical visualization and consideration of user scenario and manufacture needed to mature and finalize a design.

On the other hand, online design competitions such as '99 Designs' [29] implement the conventional design contest on the web. Because they accept only finalized designs, non-designer crowd cannot actively participate.

Many previous studies have shown the benefits and potentials of crowdsourcing, but crowdsourcing the entire design process remains largely unattempted. We assume that if crowd understands the whole design process in which ideas diverge and converge, and shares the design context with professional designers, the crowd will become better motivated and generate more relevant, higher quality ideas during different stages of design process.

CONSIDERATIONS FOR DESIGN CROWDSOURCING

To effectively crowdsource the entire design process, it is important to understand it. Thus, in this section, we explain the nature of the design process, and categorize design working styles to search for a new opportunity area on which to build a new design crowdsourcing method.

Iterative Nature of Design Process

In a design process, concept generation and controlled convergence repeat, and design ideas gradually converge to a final concept. During the initial stage divergent exploration is important; during the more mature stages, convergent decision-making is. Designers tend to collaborate to explore multitudes of ideas during the more open, divergent phases, while they tend to compete in the decision-making, convergent phases. In such an iterative process, rationales for decision-making [4] need to be shared explicitly for effective communication and contribution.

Collaborative Nature of Design Process

Designers cooperate in a design process to collect information and share ideas. Evaluation and selection of these ideas follow. During the course of these activies, a leader plays a significant role in coordinating the design communciation and finalizing the design concept [9]. The leadership is especially important in an online collaboration, since there is no face-to-face interaction and the communication channel is limited to text and figures [6, 19].

Competitive Nature of Design Process

In terms of aesthetics and style, there is no single absolute standard; design process is about searching for the most

acceptable solution within given constraints. This requires numerous decisions to be made in a design process and an unavoidable competition among designers for their design to be selected. According to a study on innovation contests [2], adding competitors increases "the likelihood of emergence of an extreme-value solution" and enhances the "overall performance for high-uncertainty problems". Similar dynamics may be applicable to design problem solving, which is one form of innovation.

Existing Working Styles in Design Process

To properly combine the two elements of design process, collaboration and competition, we have categorized and placed different design working styles on a graph of which the axes are collaboration and competition (Figure 1). We attempted to find the space of new opportunity by analyzing the graph.

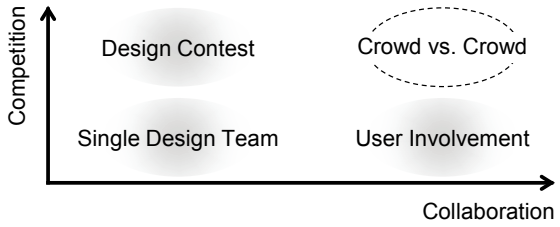

Figure 1. Design working styles categorized by the levels of collaboration and competition to find areas of new opportunity.

- Single design team: A single body is responsible for all design activities. An individual designer or an internally collaborating group of designers fall under this category. With this working style, there is no external competition or collaboration. Crowd is not involved.
- Design contest (multiple design teams): Multiple, independent bodies externally compete to win. A large number of contestants may compete for a big prize, but there is no collaboration between the contestants.
- User involvement: A single design team may externally collaborate by involving users. A typical example of user involvement is user centered design, using surveys to collect users' opinions and needs.

Opportunity Area for Crowdsourcing in Design Process

With existing working styles, either collaboration or competition dominates, or both occur at a small-scale in a single design team. No large-scale collaborative style includes both elements. By plotting existing working styles on the graph, we found out that a working style including both collaboration and competition at large-scale remains unexplored.

CROWD VS. CROWD

We propose a method for crowd participation in design, Crowd vs. Crowd (CvC) which is applicable to design tasks that require complicated and creative solutions. In CvC, a crowd of people are motivated to actively participate in design on an open platform, where they form several competing teams.

Procedure

The procedure of CvC is as follows (Figure 2).

① System construction: A system where designers will deliver intermediate and final design results and crowd will participate and communicate with each other and the designers in a design process is built. The system can either be online or offline. In case of an online system, the system may utilize an interactive webpage or a social network service.

② Designer recruitment: Designers are recruited to lead teams of crowd. Each designer is responsible for making important decisions within the team and for the quality of the final design outcome of the team.

③ Proposal and promotion: Initial proposals of designers are released and full promotion initiates. Crowd who are interested in the design problem gathers and the attractiveness of the proposals affects them in deciding to participate. For active participation of crowd, appropriate vitalization in this initial stage is crucial.

④ Team formation: At the early stage of design, each crowd participant freely chooses one or more teams. Even without any dividing wall, some participants start to settle in specific teams. Based on positive experiences of good communication and advancing design activities, participants begin to recognize themselves as the design team members.

⑤ Design development: Each designer continues to lead the crowd in each team, and develops design with the feedbacks and suggestions from the crowd members. In this stage cooperation in group boosts the design process and at the same time, competition among teams develops. At the end of this stage, each team selects and submits one design from the generated alternatives.

⑥ Design selection: The best design among the candidates is selected. Selection can take different forms, including: vote by end-users; selection by the highest decision maker; evaluation by experts.

⑦ Reward: After the final design is chosen, the winning team shares the reward. The reward is divided based on each participant's quantitative and qualitative contribution to the design. The reward can be non-financial, for example, recognition and honor within the community.

Roles of Participants

Designer

In the actual design process, the quality of the final outcome is as important as its innovativeness. Thus, the designers, who have the skills to finalize designs, are given the responsibility of ensuring the final design quality. Such

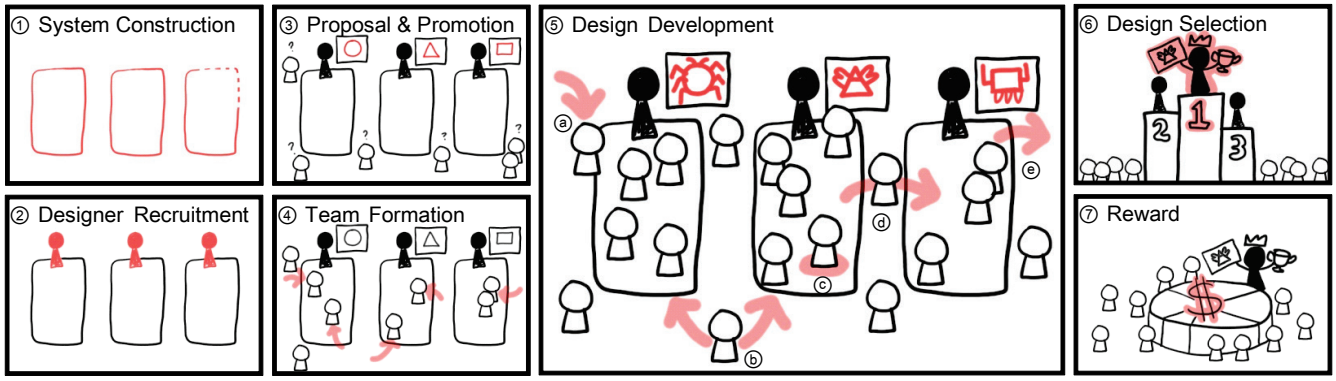

Figure 2. Conceptual overview of the Crowd vs. Crowd (CvC) design method.

a quality-control is missing in the current design crowdsourcing attempts. Without the designers' support in visualizing and finalizing ideas generated by the crowd, participation would become, in general, more demanding and less interesting. In addition, there is a risk that even when everybody is interested, nobody takes on the laborious job of finalizing designs, resulting in unfinished work.

With our CvC method, the designers give feedbacks to the crowd's comments or visualize their ideas using graphical tools, and take the responsibility of developing alternative ideas and finalizing them. Moreover, the designers also decide whether to adopt an idea of the crowd or not. Through such activities, the designers can save the time and effort required to collect relevant information, generate ideas based on them, and to gather opinions on design alternatives. The designers' expertise safeguards the quality of the final design in addition to aiding effective communication between the crowd.

Crowd

The main role of the crowd is to support the designers. The crowd members may contribute in different ways. During the early stage, the crowd can share personal experiences to inform the designers about the design context. The crowd can also search for relavant information, designs, or images and share them with the designers. During the developmental stage, the crowd may generate creative solutions with different perspectives, drawing inspiration from the designers' works in progress. Near the final stage, preferential opinions of the crowd can be used to simulate evaluation by clients, helping the designers make decisions.

At the beginning of the CvC design process, Each participant is motivated extrinsically to join (Figure 2ⓐ), for example by financial reward [22], and may take part in several teams concurrently (Figure 2ⓑ). However, as the process progresses, each participant tends to feel more attached to the design team in which his or her ideas have been responded to, and reflected in the work. Along with such attachments, factors such as the sense of connection among teammates, and the sense of loyalty may induce each participant to settle in one team (Figure 2ⓒ). In this process, individual traits such as sociality and interest for fun activities motivate participants intrinsically [22]. Each participant freely chooses and switches teams (Figure 2ⓓ), simply by preference, or out of the interest of being in the winning team and receiving the reward. A participant can also choose to opt out at any point (Figure 2ⓔ).

EVALUATION

Goals

Following hypotheses are to be verified.

- In comparison with other collaborative design methods, CvC should be able to attract a larger number of participants, with its collaborative and competitive elements triggering crowd's extrinsic and intrinsic motivations.
- CvC should be useful for designers in developing design alternatives during the design process.
- The level of competence of design outputs produced by CvC should be at least equal to those produced by other design methods, with the same time frame.

Evaluation Design

To evaluate the effectiveness of CvC, we compared it with design contest and user centered design utilizing survey (user involvement). Among the design working styles shown in Figure 1, the single design team case was excluded from the comparison, because it does not require crowd. Design contest and survey, on the other hand, require crowd participation and include elements of collaboration and competition. To fairly compare the methods, the same design task was given, on the same website. Crowd motivation and the design quality were directly compared. On the other hand, the usefulness of CvC, which was not directly comparable, was evaluated through designer interviews.

The design topic selected was a camera interaction technique specialized for taking self-pictures (Figure 3). In the absence of real stakeholders, a design topic which was interesting and could be easily visualized was selected as we needed to encourage participation from a crowd of people who were mostly unfamiliar with product design.

Figure 3. Evaluation design topic: to design a camera interaction technique that enables the user to take better self-pictures.

Evaluation was carried out for 8 days for all three methods. For the survey method, the actual survey was completed in 5 days so that the designer could have 3 days to finalize the product based on the collected information.

4 professional designers with industrial design major were recruited to gather data from crowds, and support development and finalization of designs. Each designer was paid $100 as the front money. 3 of them were assigned to use CvC and 1 to utilize the survey method. To promote participation, we advertised the event online and offline through: notifications around the campus; social network services such as Facebook and other online communities; QR code promotions. We did not collect private information apart from what was needed to transfer rewards. Participants were able to freely access all the design drafts at the CvC website and participate in the survey. In contrast, the design contest was for submission only.

For evaluation, the crowds participating in the CvC method, design contest, and survey were informed that $250 of reward in total will be distributed as follows. When a proposed CvC design is selected as the best design, each participant of the winning team will receive portions of the reward depending on his or her participation, influence on the final design, and contribution evaluated by the team's designer. When a design produced by the design contest is selected as the best design, the winner takes all the reward. When a design produced by the survey method is selected, the designer takes all the reward. In addition, every participant of the survey receives an online credit worth $0.5, with no extra rewards, even when the survey contributed greatly in the developing the winning design.

Evaluation 1: Comparison of Crowd Participation

To confirm that CvC can attract more participants compared to other design methods, we analyzed the page views and counted the number of participants for each method also.

Results

We used the number of page views as an indication of crowd participation, and compared it for the 5 pages (Figure 4): one for survey, one for design contest, and three for CvC. The percentage exceeded 90% for CvC, showing that most of the people who visited the website were interested in the design process of CvC.

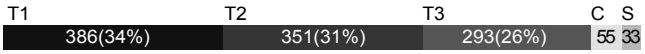

Figure 4. Number of page views (T#: CvC team #, C: Design contest, S: Survey).

The numbers of people participated in CvC, design contest, and survey are given in Figure 5. More than two thirds of the total participants applied for CvC, showing CvC's lower entry barrier.

Figure 5. Number of participants (S: Survey, C: Design contest).

Evaluation 2: Helpfulness of Crowd in CvC

To verify the helpfulness of crowd in CvC, we analyzed how the crowd's comments were reflected in the design process and also devised a survey to measure designers' satisfaction with CvC.

Reflection of Crowd's Opinions

With CvC, the crowd raised a wide variety of opinions about the designers' drafts and their developments. Such opinions were reflected in the design process by influencing the designer's decision making, with some opinions even directly affecting the final concept. For example, the ideas from the crowd include: the protection cap of the 2nd draft of Team 1; the use of multiple cameras and panoramic view in the 3rd draft of Team 1; and the material mimicking a gecko's feet in the 3rd draft of Team 2 (Figure 6).

Designer Satisfaction

We asked the 3 team designers to evaluate CvC in 5 aspects: 1) creativity of the crowd; 2) the crowd's influence on the design process; 3) the crowd's influence on the final design; 4) valuableness of the ideas excluded from the final design; 5) overall satisfaction of the designers. Full credit for each was 7 points. The crowd was creative (5.0 points on average over the 3 team designers); they had a positive influence on the design process (5.3) and on the final design (5.3); the ideas the designers chose not to include were somewhat valuable (4.0); the designers were overall satisfied (5.3). The net average for all criteria was 5.0 points, suggesting that the collaborateon between the designers and the crowd was effective and satisfactory.

Evaluation 3: Design Quality of CvC

Because this is a virtual design problem without real stakeholders, we conducted an expert evaluation for the 5 final designs produced by CvC, design contest and survey. The evaluators were 13 design experts, industrial design majors with at least 6 years of professional design trainings.

The evaluation was carried out in two ways. First, each design was ranked from the 1st to 5th. Second, scores were given on Likert scale, according to the evaluation criteria of *Concept Design Section* of *Red Dot Award,* one of the internationally renowned design competitions (Figure 7).

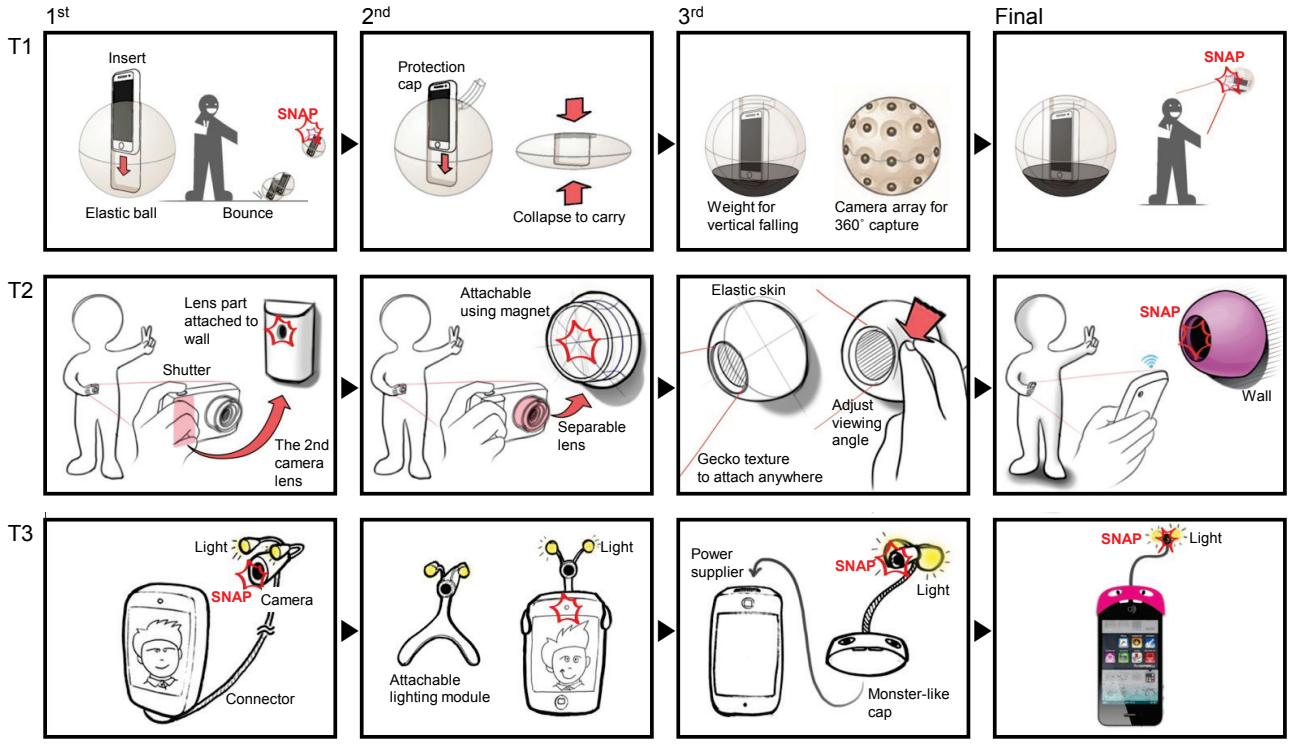

Figure 6. Design progress in each team in CvC (T#: CvC team #).

Results

For the relative ranks, we used chi-square analysis on the frequency of each design selected as the best. Team 1's design from CvC was the best, regarded as the best design by 58.3% of all evaluators. The result regarding the frequency of selection was statistically valid (χ^2=14.038, df=4, p<0.05).

For the scores, according to repeatedly-measured ANOVA, the design of Team 1 was also selected as the most prominent and showed excellence in degree of innovation (F=4.65, df=2, p<0.05), aesthetic quality (F=11.88, df=2, p<0.05) and emotional content (F=8.27, df=2, p<0.05) among the seven criteria.

Based on the result of the evaluation, the reward was distributed to the 22 participants of Team 1. The portion of the prize that each received was decided based on the number of comments and on the designer's evaluation of the level of contribution. In comparison with the design contest method, the reward of CvC was relatively small, but participating as crowd would be much easier than trying to win a contest. In addition, the smallest amount granted to a participant in Team 1 was $1.5, still three times larger than the reward for the survey participation, $0.5. The most active participant was granted $62.25 which was 25% of the total amount, $250. The top 6 active participants (27% of participants of Team 1) received $171.5, which amounted to 70% of the total reward.

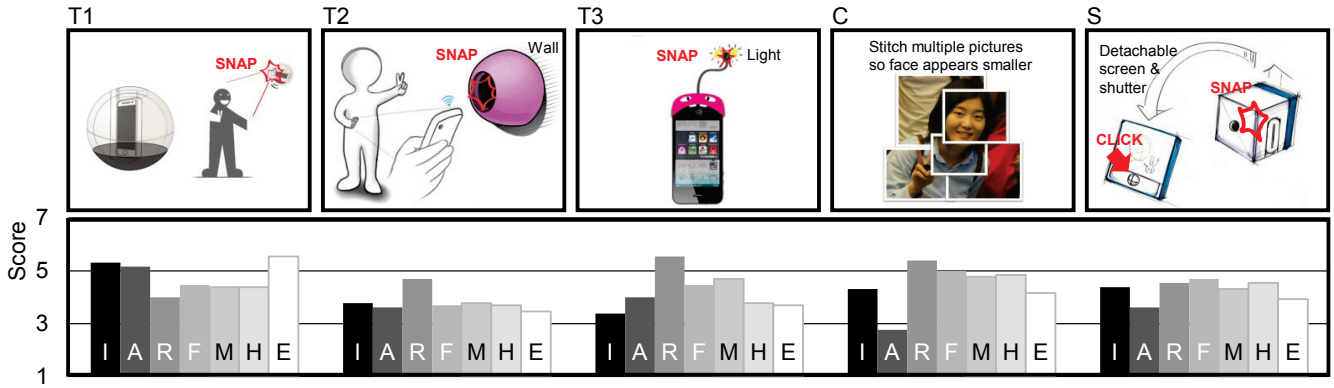

Figure 7. Evaluation of designs produced (T#: CvC team #, C: Design contest, S: Survey) in terms of degree of innovation (I), aesthetic quality (A), realization possibility (R), functionality and usefulness (F), manufacturing efficiency and cost of manufacturing (M), ergonomics and human interface (H), and emotional content (E).

APPLICATION TO TWO REAL DESIGN PROBLEMS

We applied CvC to two logo design projects, to evaluate CvC's usefulness and effectiveness in a situation where the real needs of the users and the stakeholders are present. In Application 1, we analyzed crowd participation qualitatively, and in Application 2, quantitatively.

With the two real-life applications, we were able to compare CvC with other design methods mapped on Figure 1. In Application 1, we compared CvC with an open design contest. In Application 2, we compared CvC to design work performed on a contractual basis, by a design company, i.e. single design team.

Application 1: Logo Design of a Chemistry Department

We tried to apply CvC to solve an actual design problem where the stakeholders and their needs were real and well-defined. The selected topic was a logo design for the department of chemistry in a university.

CvC was carried out concurrently with a design contest which had started a week earlier. CvC lasted for 9 days, and 3 additional days were given for each team's designer to finalize the logo design. To select the best design, a departmental poll was held for 5 days.

Since the logo needed to reflect the characteristics of a chemistry department, one designer and one chemistry department student were assigned to lead each team and receive supports from the crowd. All members of the department including the professors, graduate students, undergraduate students, and staffs were asked to participate as crowd because they were the actual users of the final design. The crowd was able to view the design processes of all designers and their supporters.

The front money for each designer was $100. The total reward was $500. If a design from the design contest won, the winner could take the entire prize. If a design from CvC won, the team designer could receive $200 with the team members sharing the other $300 depending on participation and contribution as evaluated by the designer.

A departmental poll was held to determine the final logo design. There were 8 candidates to vote for: 4 designs from the 4 CvC teams and 4 designs from the design contest selected by the department administration. The voters were asked to choose one logo design and evaluate it in terms of satisfaction, on a 100 point scale.

Results

4 CvC teams successfully finalized their designs. In addition, 30 designs were submitted to design contest in total, and 4 were selected (Figure 8). 306 people from the department voted. Among them, 211 people voted for the designs from CvC, accounting for 72.2% of votes casted (Figure 9). The selected final logo was one from Team 2 which received 86 votes (28.1%) and 83.9 points for satisfaction out of 100. The logo design by Team 1 took the 2nd place, which received 80 votes (26.1%) and 86 points.

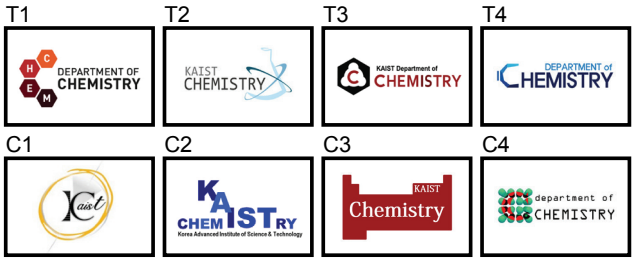

Figure 8. Results of the department logo design (T#: CvC team #, C#: Contestant #).

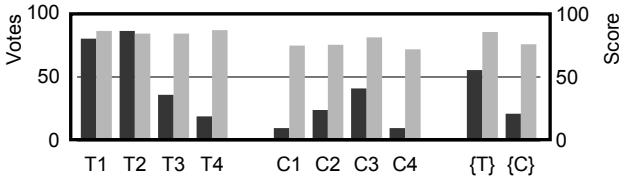

Figure 9. Votes and satisfaction level for each candidate (T#: CvC Team #, C#: Contestant #, {T}: Average of all CvC teams, {C}: Average of design contestants).

Observations

We observed the public participating through both collaboration and competition in an actual design problem solving. The designer and the crowd played the roles we expected them to. We also noticed a few interesting events as follows.

When ideas diverged, the crowd provided a rich source of opinions on how to develop the design. One example was suggestion of colors and motifs for logo design. For example, use of blue color signifying stability and motifs of steroids and double-bonds were proposed by the chemistry-savvy crowd. In addition, various information voluntarily collected by the crowd allowed the designers to expand their thoughts and diversify their design ideas.

The crowd also contributed in convergence of ideas, helping the designers make design decisions. The designers referred to the crowd's opinions in deciding whether to pick up certain ideas or not. The crowd also gave feedbacks from the viewpoints of stakeholders; they exhibited preferences on design alternatives and made choices.

An unexpected event was the emergence of a self-promoted designer. Initially the design process had started with 4 design teams. However a crowd participant actively uploaded design ideas on one of the designer's page and called out for attention. We granted him the status of a designer, and gave him his own page to form a new team.

This newly emergent team, however, dropped out prematurely and did not submit the final design. One of his crowd alerted others that the logo design uploaded by the new designer very much resembled a logo from the web. Many comments suspecting plagiarism followed. This incident seemed to have played a critical role in the designer's resignation. In CvC, crowd does not only play a passive, supporting role but also checks on designer's mistakes.

Even though CvC was carried out anonymously, some members were aware of the identities of some other members because the majority of the crowd was of the same department. This drew interest within the department, and competition heated up between some design teams. Competition was particularly intense between two teams to the very last moment of the poll. These were the two teams that took the first and the second place in the final poll. Such a competition seemed to induce attention and participation of the crowd, positively enhancing the design process and also the final outcome.

Application 2: Logo Design of a Small Tech Company

CvC was applied to design a logo for a company that produces sound and vibration measurement instruments. The company had already worked with a design company for 6 weeks, and received 8 logo candidates to choose from. We produced 6 additional candidates using CvC, to compare them against the logos produced by the design company, i.e. single design team, on a contractual basis.

We conducted CvC for 8 working days; designers updated for 4 days consecutively, took a break for 2 days during the weekend, and updated again for the following 4 days. Such segmentation enabled us to make chronological comparisons. The final design candidates were submitted on the last day, with a company-wide poll conducted on the next morning.

3 industrial designers were recruited. Similar to the case of logo design for the chemistry department, one designer and one employee from the company (the 'teammate') were assigned to lead each team and receive support from the crowd. All 15 employees of the company participated. In addition, the company sent out promotion e-mails to its business partners so that they could also take part. Only the company employees were asked to provide private information, for analysis purposes only. CvC was conducted anonymously.

The total sum of reward was $2,100. The front money for the 3 teams was $900: 3 × (designer $200 + teammate $100). The winning design team could receive $600: designer $400 + teammate $200, with one-day paid leave. The winning team's crowd shared $600. A participant in the winning team received 1 point for each comment contributed to the winning team, with additional 5 points if the designer evaluated it as a valuable comment. The $600 was distributed proportionally according to the points earned.

There were 15 design candidates: The present logo + 8 design candidates produced by the design company + 6 design candidates produced by CvC, 2 each from the 3 teams. In addition, we conducted a company-wide survey, and asked the employees to evaluate each design candidate in terms of aesthetics and expressiveness of the company identity, on 7 points Likert scales. Employees could write a short comment for each design candidate, and choose one design he or she liked the most. Lastly, the president of the company gave each design candidate a satisfaction score out of 100 points, and also wrote a comment for each. He considered the employees' opinions by referring to the survey result, and chose one final logo design.

Results

The 15 design candidates are shown in Figure 10.

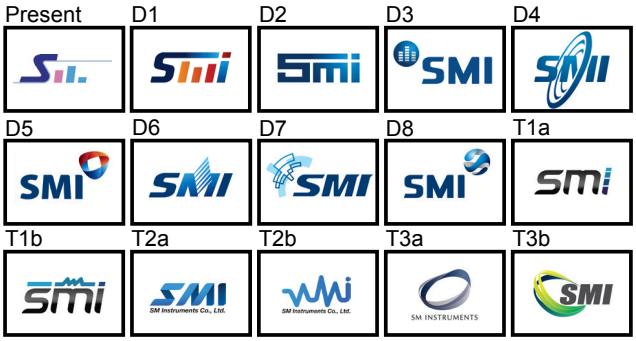

Figure 10. Results of the small tech company logo design (D#: Design # by the design company, T#a&b: CvC team #'s two designs).

13 out of 15 employees completed the survey. T3b, a design candidate produced by CvC, scored the highest overall, when evaluated in terms of expressiveness of the company identity and aesthetics on 7 point Likert scale. The average score of CvC candidates (identity 4.2, aesthetics 4.0) were higher than that of candidates produced by a design company on a contractual basis (identity 3.3, aesthetic 3.0).

In addition, we asked the 13 employees about the design candidate he or she liked the most. The result organized by design methods is shown in Figure 11. CvC designs won 9 votes (69%), showing the employees' satisfaction with the designs they contributed in making. T3b, in particular, received 4 votes (23%).

The president gave 90 points, the highest, to T3b, while giving 78 points for the 15 design candidates on the average, and 80 points for the present logo. He commented that the

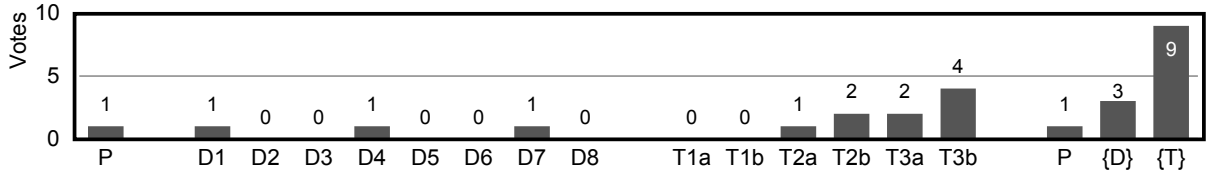

Figure 11. Votes for each design candidate (P: Present logo, D#: Design # by the design company, T#a&b: CvC team #'s two designs, {D}: All designs by the design company, {T}: All designs by the CvC teams).

T3b candidate "expresses the high levels of sophistication and creativity the company strives for," and that "the candidate would make a fine logo with minor changes on the font type and colors." This logo design was attained with CvC effectively at about 10% of the price the company paid to the design company.

18 people contributed to Team 3, and shared the $600 reward in accordance with their contribution levels. The smallest amount granted was $4, and the highest $210. Top 5 contributors took 82% of the entire award.

Analysis on Crowd's Behaviors

To quantitatively analyze the interaction between the designers and the crowd, we analyzed the number of comments written by the designer and the crowd of each team, for each day. There was a positive correlation between the numbers of comments (Pearson's $r=0.725$, $n=24$, $p=0.0005$, one-tailed). This result shows that the more active the designer is in engaging the crowd, the more responsive and communicative the crowd is.

Figure 12 visualizes the number of unique visitors and the number of comments throughout the CvC period. Both were higher during the 1st half of the period, and lower during in the 2nd half of the period, with statistical significance ($t=2.253$, $df=6$, $p<0.05$ for the number of unique visitors, and $t=2.845$, $df=3.056$, $p<0.05$ for the number of comments). There was no statistically meaningful deviation from Day 5 to Day 8. One additional observation is that the peak for the number of unique visitors was on Day 2, whereas it was on Day 3 for the number of comments. This may be because the crowd spectated on the website until they found the process interesting enough to participate.

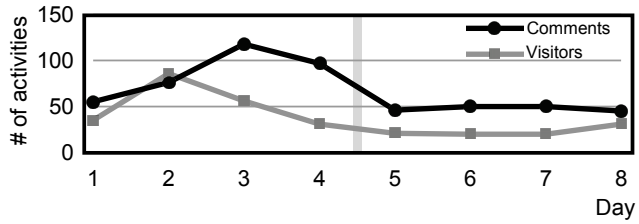

Figure 12. The number of unique visitors and the number of comments throughout the CvC period.

We also observed that each crowd member contributed in a fewer number of teams, when we compared the 2nd half of the period to the 1st half of the period (mean=-0.353, $t=-1.852$, $df=16$, $p<0.05$). This result shows the settling behavior, which we expected from the earlier evaluation and application.

CONCLUSION AND FUTURE WORK

In this paper, we first analyzed existing design working styles in terms of competition and collaboration, and discovered an opportunity area on which to develop a new design crowdsourcing method. Then we proposed the CvC method where open competition of multiple teams motivates the crowd to participate and collaborate actively. We quantitatively and qualitatively examined the feasibility of CvC through an initial evaluation case and two real-life application cases. Our findings are:

- CvC can crowdsource the entire design process, to solve a complex and creative design problem.
- CvC is easy to understand and is engaging for non-designer crowd. The crowd intuitively finds various ways to contribute during different phases of design process under the leading designers' appropriate coordination and technical assistance. Intrinsic and extrinsic motivations arising from elements of competition and collaboration sustain the crowd's participation.
- CvC is useful for designers, as the crowd helps the designers collect valuable design materials, explore a wide range of ideas during the divergent phases, and also make decisions during the convergent phases. The designers are better supported when they respond to the crowd's feedbacks and opinions faithfully.
- CvC produces competent design outputs by holding the designers responsible and leveraging on their expertise for development and finalization of design.
- CvC is particularly effective when the stakeholders of design participate as the crowd. They are eager to help design what is meaningful to them, actively contribute by sharing their community-specific knowledge, and find such an activity fulfilling. They tend to be more satisfied with the design they helped to create, meaning that CvC can be applied to resolving various public design issues.
- CvC is cost competitive and transparent.

As future work, we will explore interfaces to assist crowd activity. We will also study application of CvC at a much larger scale, which would highlight more practical issues. In addition, approaches of computational social science will be used to analyze social dynamics within CvC.

ACKNOWLEDGEMENT

We thank: Jeong-Ro Yoon, Youn-Kyung Lim, the members of I²DEA Lab, and the reviewers for their invaluable comments and assistance; Young-Key Kim (CEO, SM Instruments, Inc.) and Sang Kyu Kim (Head, Department of Chemistry, KAIST) for cooperating with us in CvC applications; all the designers and crowd members for participating in CvC.

REFERENCES

1. Be a Martian, http://beamartian.jpl.nasa.gov/
2. Boudreau, K., Lacetera, N., and Lakhani, K. (2011). Incentives and problem uncertainty in innovation contests: an empirical analysis. *Management Science 57*, 5, 843–863.
3. Brandes, U., Stich, S., and Wender, M. (2008). *Design by Use: The Everyday Metamorphosis of Things*, Birkhäuser.

4. Buxton, B. (2007). *Sketching User Experiences: Getting the Design Right and the Right Design*, Morgan Kaufmann.
5. Cooper, S., Khatib, F., Treuille, A., Barbero, J., Lee, J., Beenen, M., Leaver-Fay, A., Baker, D., and Popović, Z. (2010). Predicting protein structures with a multiplayer online game. *Nature 466*, 7307, 756-760.
6. Cranshaw, J. and Kittur, A. (2011). The polymath project: lessons from a successful online collaboration in mathematics. In *Proc.CHI 2011*, 1865-1874.
7. Dow, S., Kulkarni, A. Klemmer, S., and Hartmann, B. (2012). Shepherding the crowd yields better work. *In Proc. CSCW 2012*, 1013-1022.
8. Heimerl, K., Gawalt, B., Chen, K., Parikh, T., and Hartmann, B. (2012). CommunitySourcing: engaging local crowds to perform expert work via physical kiosks. In *Proc.CHI 2012*, 1539-1548.
9. Joseph, M. and Reagle, J. (2007). Do as I do: authorial leadership in wikipedia. In *Proc. WikiSym 2007*, 143-156.
10. Kanefsky, B., Barlow, N., and Gulick, V. (2000). Can distributed volunteers accomplish massive data analysis tasks? *Lunar and Planetary Science 32*, 1272.
11. Kensing, F. and Blomberg, J. (1998). Participatory design: issues and concerns. *Computer Supported Cooperative Work 7*, 3, 167-185.
12. Kittur, A., Chi, E., and Suh, B. (2007). Crowdsourcing user studies with Mechanical Turk. In *Proc.CHI 2008*, 453-456.
13. Kittur, A. (2010). Crowdsourcing, collaboration and creativity. *XRDS 17*, 2, 22-26.
14. Kittur, A., Smus, B., Khamkar, S., and Kraut, R. (2011). CrowdForge: crowdsourcing complex work. In *Proc.UIST 2011*, 43-52.
15. Kittur, A., Khamkar, S., André, P., and Kraut, R. (2012). CrowdWeaver: visually managing complex crowd work. In *Proc.CSCW 2012*, 1033-1036.
16. Kulkarni, A., Cam, M., and Hartmann, B. (2012). Collaboratively crowdsourcing workflows with turkomatic. In *Proc.CSCW 2012*, 1003-1012.
17. Lakhani, K., Hila, L., and Tushman, M. (2012). Open innovation and organizational boundaries: the impact of task decomposition and knowledge distribution on the locus of innovation. *HBS Working Paper 12-057*, 1-53.
18. Little, G., Chilton, L., Goldman, M., and Miller, R. (2009). TurKit: tools for iterative tasks on mechanical Turk. In *Proc.HCOMP 2009,* 29-30.
19. Luther, K. and Bruckman, A. (2008). Leadership in online creative collaboration. In *Proc.CSCW 2008*, 343-352.
20. Piller, F., Schubert, P., Koch, M., and Möslein, K. (2005). Overcoming mass confusion: collaborative customer co-design in online communities. *Journal of Computer-Mediated Communication 10*, 4, 1-25.
21. RECAPCHA System, http://recaptcha.net/
22. Ryan, R. and Deci, E. (2000). Intrinsic and extrinsic motivations: classic definitions and new directions. *Contemporary Educational Psychology 25*, 1, 54-67.
23. Salganik, M. and Levy, K. (2012). Wiki surveys: open and quantifiable social data collection, *ArXiv e-prints.* 1-29. http://arxiv.org/abs/1202.0500/
24. Sullivan, B, Wood, C., Iliff, M., Bonney, R., Fink, D., and Kelling, S. (2009). eBird: a citizen-based bird observation network in the biological sciences. *Biological Conservation 142*, 10, 2282-2292.
25. Tang, A. and Boring, S. (2012). #EpicPlay: crowdsourcing sports video highlights. In *Proc. CHI 2012*, 1569-1572.
26. The Johnny Cash Project, http://www.thejohnnycashproject.com/
27. Xu, A. and Bailey, B. (2012). What do you think?: a case study of benefit, expectation, and interaction in a large online critique community. In *Proc. CSCW 2012*, 295-304.
28. Yu, L. and Nickerson, J. (2011). Cooks or cobblers?: crowd creativity through combination. In *Proc.CHI 2011*, 1393-1402.
29. 99 Designs, http://99designs.com/