THE APPLICATION OF CROWDSOURCING FOR 3D INTERIOR LAYOUT DESIGN

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Abstract

Since the activity was first defined in 2005, the use of crowdsourcing has been investigated by researchers in various domains (i.e., open innovation, linguistic study, commercial collaboration, etc.). However, less is known about the use of the crowdsourcing as a tool for collaborative design. Although the crowdsourcing has been used to carry out generative design, there are still many gaps in knowledge about the capability and limitations of the technology. For example although researchers have reported the use of the "crowd" to combine and evaluate designs, the application have been limited to hand sketches or 2D layouts. This paper assesses how well crowds can combine and evaluate 3D designs. An experiment, described in terms of the Crowdsourced Design framework, is presented for the collaborative creation and iterative improvement of a 3D layout. The results of the experiment make two contributions; firstly it demonstrates that 3D design can be carried out as effectively as 2D using open, could-based tools; secondly, the cDesign framework can be mapped on to the activities required to support 3D crowdsourced design tasks on the commercial crowdsourcing platform.

Keywords: Crowdsourcing, Collaborative design, Design methods, Crowdsourced Design (cDesign), 3D design

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1 INTRODUCTION

In the information age, design can be a product not only of individuals but may also result from the combined efforts of many people. Although such collaborative design systems are well documented in the literature for design activities carried out by, say teams of professional engineers and architects (Whitfield et al. 2002) less is known about the potential of distributed, anonymous, crowd-based collaboration in creative tasks. In contrast to the established processes academic research into crowdsourced design has investigated the power of iteration, competition, reward and combination processes (Wu et al. 2014b; Yu & Nickerson 2011). Although in various forms of 2D design crowdsourcing has been validated as an effective tool, its application in 3D design has been less investigated. The aim of the work reported in this paper is to investigate if creation and evaluation processes for 3D designs can be crowdsourced via an open commercial crowdsourcing site. The objectives implicit in this goal are to establish an effective framework and CAD tool for creating and sharing 3D designs between online workers. The paper first describes the cDesign framework used to structure the creation of a 3D design task on a commercial crowdsourcing platform and then presents the results of an experiment to test the effectiveness of the application.

1.1 Crowdsourcing

In 2006, "crowdsourcing" was defined by Jeff Howe 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"(Howe 2006). However, these people do not have the same composition as the internal company "crowd" discussed earlier. This new type of "crowd" is made up by anonymous groups (Yochai Benkler 2006). In this crowd, members do not know each other; they usually undertake tasks individually, and then if their results are accepted, they will be rewarded by typically small amounts of money. (Kittur, Ed H. Chi, et al. 2008). Crowdsourcing groups include online product communities (Brabham 2009; Jeppesen & Frederiksen 2006; Kozinets et al. 2008), virtual communities of special interests (Hogue 2011), the general public (Chilton 2009; Haklay & Weber 2008), and employees who typically would not participant in the tasks to be completed (Stewart et al. 2009). Since 2006, the Human-based Genetic Algorithms (HBGA) has emerged as the principle way to support design using crowds as the next section describes the HBGA requires designs to be combinable (i.e., merge distinct features) and also evaluable. The experiment presented here seeks to establish if this true for 3D layout tasks. The paper is structured as follows: the coming paragraphs present a brief review of crowdsourcing's application in design domain, followed by a fundamental Crowdsourced Design (cDesign) framework (section 2); then the paper presents the detailed processes of the application of the framework in a 3D interior layout design task (section 3&4). In section 5, there is a discussion of the differences between the application of the cDesign framework in 2D and 3D design, and a brief comparison of the experiment results and the reported work. Finally, the paper is ended with the conclusion, the limitation of the experiment and the recommendations for the future work in section 6.

1.2 Collaborative crowdsourced design

Unlike the competition model system (i.e., Taskcn (Anon n.d.; Wu et al. 2014a)) where the design work is ultimately done by individuals, collaborative design requires the merging or selective combination of ideas (Yang et al. 2008; Liu & Yang 2011). One of the most impressive methodologies to emerge for collaborative, crowdsourced design is the **Human-based Genetic Algorithms (HBGA)** method that has been used for generative innovation tasks (Yu & Nickerson 2011; Yu & Nickerson n.d.; Yu & Sakamoto 2011). The approach uses selective combinations to develop creativity (Osborn 1957; Amabile n.d.), and has been applied to a number of different applications (Yu & Nickerson n.d.; Yu & Nickerson 2011; Bao et al. 2011). This is a theoretically appealing approach because it has been suggested by some researchers that creative design comes from combinations (Amabile n.d.). In the HGBA, new ideas are basically separated into different generations. In the first generation, participants from the crowdsourcing platform create the first group of designs. Then a second crowd evaluates the first generation and chooses several pairs for the combination process to construct the second generation (i.e., generation 1 evaluation). In generation 2, some of the ideas were selected directly from the top ranked generation 1 designs, and others were collected by combining pairs chosen from the first generation (i.e., generation 2 combination). Then, the third generation applies the evaluation process to the second generation combination process again to create generation 3 (Yu & Nickerson n.d.; Yu & Nickerson 2011). So, iteratively, generation after generation, new ideas could be sequentially created.

The HBGA and competition model (i.e., Taskcn) methodologies are clearly effective, for the design domains they have been applied to free hand sketches or 2D layouts. The objectives of this paper are: 1, to investigate if HBGA can support 3D layout design; 2, to investigate the applicability of the crowdsourced design (cDesign) framework to 3D design tasks. The hypothesis of the result is that the 3D design can be crowdsourced, and the cDesign framework is appropriate to both 2D and 3D design tasks. The next section presents the general cDesign Framework as well as the specifics of its application in 3D design methods.

2 METHODOLOGY - THE FUNDAMENTAL CDESIGN FRAMEWORK

Despite its apparent diversity the process of mechanical design has been formalized by models such as Pugh's "Total Design" (Pugh n.d.) or Pahl and Beitz's method (Pahl et al. 2007). These models of the design process provide a reference framework which enumerate the criterial steps and allow previously "ad hoc" activities to be structured and managed. The cDesign model presented in this section is motivated by the desire to provide a similar structure to the process of creating crowdsourced design tasks. Thus the objective of the framework is to define the structure within which a particular refinement or evaluation process (i.e., Yu's HBGA) can be applied. The cDesign model details all the stages of crowdsourced design activity starting from the crowdsourced design specification, and ending with the evaluation of the resulting design. The model is shown schematically in figure 1 and consists of four major stages: Specification, Prototype, Execution and Evaluation. The framework provides a structure for describing the authors' investigations (rather than being, say, a provable optimum model for crowdsourced design). The following sections provide a qualitative description of the stages before the experimental work in support of the design evaluation process used in Stage 2, 3 and 4 is presented.

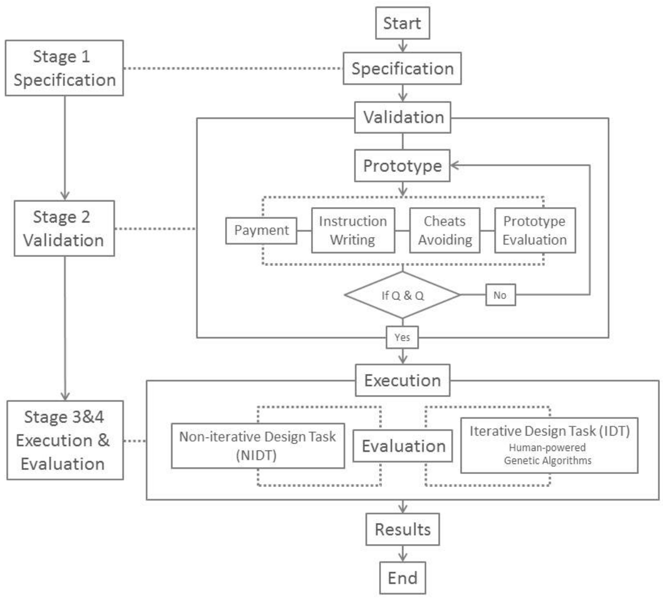

Figure 1. cDesign methodology framework's main stages

Each of these stages can be expanded into a specific checklist of issues and options that must be addressed by the creators of crowdsourced design tasks, which are shown in the following paragraphs.

Stage 1: The Specification Stage comprises tasks such as: Platform Selection, Design Tool Selection, "Crowd" Selection, Methodology Selection and Design Workflow. Every design task needs a crowdsourcing platform to host the process and the choice of crowdsourcing platform will reflect the nature of the task: some of the design work can be attempted by anyone regardless of education or background, whereas other tasks require specific experience or education. For example, Amazon's

Mechanical Turk (MTurk) and ShortTask involve workers from all over the world. In contrast, some platforms are only for workers from one country, for example the Taskcn platform has workers mostly from China. After selection of the platform the choice of design representation or tool is the second most important step. Design tools need to be selected for workers as a consideration of the task itself (i.e., 2D design task – 2D design tools or 3D design task – 3D design tools). There are several considerations of design tool selection which are discussed in the section of Experimental Design. Furthermore, the "crowd" provided by a given platform needs to be selected and consideration given to any skills they might require. In parallel to the fundamental decisions on platform, tool and crowd, the methodology to be adopted in the execution process must be determined at this initial stage. For example, the design task processes can be iteratively or non-iteratively executed. Finally, once the methodology is specified the design workflow needs to be discussed (i.e., results' file transfer, shared access to a representation held in the cloud, etc.).

Stage 2: Without prior experience of running similar tasks many of the choices made in the specification stage will be educated guesses whose effectiveness is uncertain. There are 6 implementation decisions that need to be specified and validated in Stage 2: the payment for participants; time to undertake the task; clarity of the task instruction; results submission method and the manner in which workers who attempt to scam, or cheat, the system should be handled.

The design of the crowdsourcing task is refined through the process of prototype testing until the require Quantity and Quality (Q & Q) of results are being produced. At which point the process moves to the Execution.

Stage 3 & 4: Execution is essential a scaling up of the task for presentation to a larger crowd. The length of the execution stage will be determined by the method set in Stage 1. A competition might last many weeks whereas a Human-based Genetic Algorithms (HBGA) will often cycle through generations of design every few days. In terms of the Evaluation process, regardless of the mechanism used the process ends, with a review of the generated design by a panel of experts who review the crowd's work and select the best outputs. At both the validation and execution stages the ability to accurately evaluate designs is crucial to tasks such as the setting of payment levels (Stage 2) or selecting the best design for iterative improvement (Stage 3). The next sub-section describes an experiment, in terms of the cDesign framework, that was created to investigate the framework's application in 3D design area.

3 EXPERIMENTAL DESIGN - 3D INTERIOR DESIGN EXPERIMENT

The cDesign Framework has been applied to a 2D interior design task to investigate the relationship between design quality and the payment for workers (Wu et al. 2014b; Wu et al. 2014a). However, to investigate the application of the cDesign framework to 3D design, an HBGA based kitchen layout task was devised. The following sections describe the creation of this task in terms of the cDesign framework. Kitchen designing has often been used as a vehicle for academic research (Fischer et al. 1989; Nomura et al. 2001; Fukuda et al. 1997), because it offers a creative task that is both "open" to many (and so suitable for public crowdsourcing) and accessible (i.e., the results can be objectively quantified).

3.1 Stage 1: Specification

The nature of the design brief will determine the platform, design tools, crowd type, methodology and workflow. In this case, a public crowdsourcing platform (MTurk) was selected rather than a specialise site (e.g., GrabCAD for engineering, or Taskcn for graphic design experts). From the reported papers, MTurk can be selected as an effective tool to get work done quickly and at minimal cost. What is more, all people using the internet and having an account on the crowdsourcing platform would be welcome to participate in the design as well as the subsequent evaluation experiments.

In terms of the design tool, from prior experience of crowdsourced design tasks (Wu et al. 2014b; Wu et al. 2014a) a review of previous research that the CAD tools used for public crowdsourcing sites should contain the following features: first, they should have minimal barriers to use (i.e., low cost or free, little or no installation, no registration); second, be easily learnt (so workers who have never used the tool before can still undertake the task); 3rd, use a standardized file format (to enable easy processing of results and organizing files). In the process of creating the design experiment, the following free & cloud based 3D design tools were considered: "Build with Chrome TM", TinkerCAD TM and Homestyler TM. Finally the Homestyler was selected as the modelling tool. The reasons can be summarized as follows: although "Build with Chrome" is extremely easy to use, the results could not be saved, download and shared between different accounts (i.e., workers and solution seekers). Secondly, after running the pre-experiments of the last two tools, it was obvious that TinkerCAD is a more open-ended platform, which means participants could easily submit nominal work (i.e., a simple and crude geometrical solid, instead of a 3D kitchen model) in an attempt to cheat the system. What is more, in Homestyler, there are already a large number of kitchen utensils/decorations/appliances (i.e., microwaves, cooking bench, tables, chairs and range hood, etc.). So participants could focus on designing the layout of kitchen model. Additionally, the layout design model could be saved as "public" so that participants could share the results by the URL links, which provide the possibility of design collaboration.

When considering the methodology selection, there are two generic crowd design methodologies namely 1) linear competition (non-iterative) and 2) iterative improvements. Compared with the linear competition, iterative improvement can range from the very structured HBGA process to a looser process, where workers compete for bonus payments by improving on previous solutions. In Stage 1, it is sufficient that the high level methodology is fixed. This choice will allow the workflow to be defined. In the case of the 3D interior design layout task, it was decided that an iterative process would be suitable since the objective is to generate designs and importantly, use the crowd to improve designs as well as evaluate them. The experiment's process is illustrated as Figure 2.

1. Participants on MTurk create designs marked as the 1st Generation (G1) (design task).
2. G 1 designs were evaluated on MTurk to select the top 3 designs (evaluation task).
3. The top 3 designs are then combined with each other to create the combination generation (C1= No.1 combines No. 2, C2=No. 2 combines No. 3, C3=No. 1 combines No. 3, 'C' means combination), and each combination design collects three results (combination task). For each 3 combination design groups, participants would evaluate them to select the best combination designs (3 best designs: C1B, C2B and C3B) (evaluation task).
4. Final evaluation: integrate the best combination designs (C1B, C2B and C3B) and the top 3 designs from G1, and then evaluate them (evaluation task).

Figure 3 shows examples of the kitchen layouts developed in "Homestyler".

3.2 Stage 2: Validation (Prototype)

Generally, when posting a task on a crowdsourcing platform, the parameters required are: 1), the payment for workers; 2), how much time should be given to workers; 3) how they submit their solutions; 4) how to avoid cheats. Then the task instruction can be integrated.

In cDesign applications researchers have reported that there is a weak correlation between the level of payment and the average quality of results (Wu et al. 2014b). These are generous payment levels in comparison to other reported research studies which could be as low as \$0.01 (Paolacci et al. 2010), \$0.10 (Kosinski & Bachrach 2012; Paolacci et al. 2010). And the payment on the platform used is rarely over \$1.00 (Paolacci et al. 2010), only some translation jobs might be paid as much as \$1.40 per hour (Horton & Chilton 2010). However after the pre-experiment in which participants were paid \$0.50, only six results (including cheats) were collected. As a result, the authors increased the payment to \$1.00.

Additionally, based on observation and prior experience of working on MTurk, it was found that for even a simple task, requesters would give enough time to participants for undertaking the task. In the previous 2D layout design experiment (Wu et al. 2014b), participants had an hour to submit their work. Because the 3D layout design task is more complicated than the previous 2D tasks reported by the authors, crowd workers were given one and a half hours. Also, in the design combination task, workers were paid \$1.00 for design combining in one and a half hours.

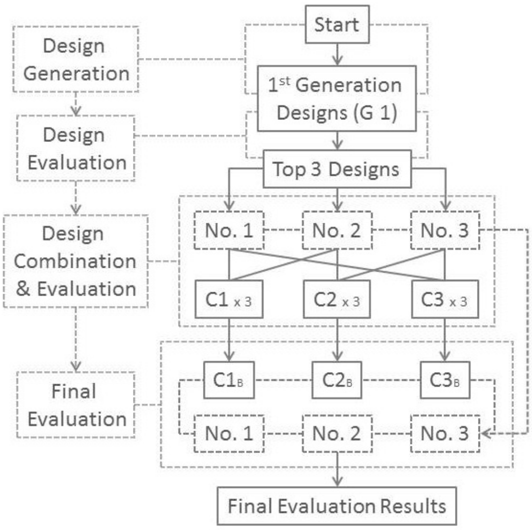

Figure 2. The workflow of the 3D kitchen layout design experiment

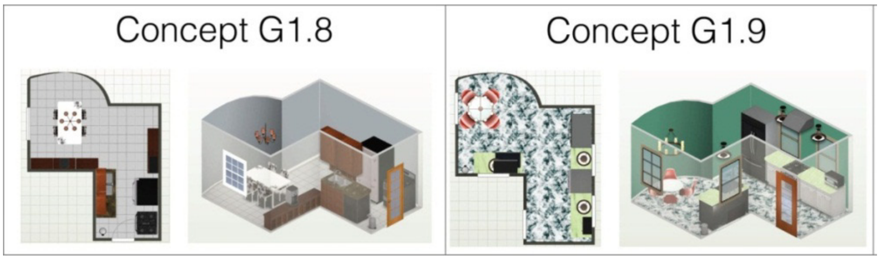

Figure 3. Examples of the kitchen designs by Homestyler

As for the layout results submission, because the native Homestyler files could not be submitted via MTurk directly, so instead when workers finished their design (as well as design combinations), they would have to "share" the results (saving the result as "public" in Homestyler and sending an email to the authors) and also submitting a screen-shot of the results via MTurk (so that they could get paid).

In addition, in crowdsourcing platforms, a number of workers always attempt to subvert the system (Eickhoff & Vries 2012)(Wang et al. 2012)(Little et al. 2009). In this experiment, the authors chose the following methods to validate submissions. Based on the fixed design tool, participants would need to share a URL to their Homestyler design with the authors (instead of just submitting results on MTurk), which would then require workers to design the layouts by themselves (and so avoiding people simply submitting random images).

Once the above decisions had been made the focus turned to the writing of the task instruction. Several drafts were reviewed to make sure the text was easy to understand and as clear as possible. The following link shows the final instructions for the design task: http://tinyurl.com/ngy3fcw. After the design workflow was fixed, the task was made available on the Crowdsourcing platform for a small number of workers to test the job's design. The researchers judged the prototype results by their quality and quantity (i.e., Q & Q). As a result, after the evaluation showed that the results satisfy the Q & Q, the design and its workflow was deemed suitable to move to the Execution Stage. If this had not happened the prototype would needs to be corrected, until it reaches the Q & Q threshold.

3.3 Execution

Based on the cDesign methodology framework, there are two main choices in the design execution: Non-iterative Design Task (NIDT) and Iterative Design Task (IDT). From the section above it can be seen that this experiment was applied to the iterative design method. After the Prototype Design stage, the design method, platform, payment and the design tool were all validated such that the task could collect design results in acceptable quality. The following sections discuss the design results, design evaluation method and the evaluation results. Since the main purpose of the design experiment was to investigate how crowdsourcing as a tool could be applied to 3D design, the authors employed the iterative design method. The interior 3D design task was completely (after validation of the design prototype) and in total 10 approved 3D layout designs were collected as the 1^{st} generation designs (G1).

3.4 Evaluation

Crowds can design (Wu et al. 2014b; Yu & Nickerson 2011), and crowds can evaluate design (Bao et al. 2011). Therefore, after collecting the 10 results as the 1^{st} generation, the evaluation task was then posted on MTurk (also, the combination designs' evaluation task applied to the same evaluation method). In the evaluation process, in total, 10 criteria were provided to workers with the 5-Point Likert Scale to be judged: 1 means very bad and 5 means excellent (the 10 criteria are available at: http://tinyurl.com/obogswv). The Google Drive platform was used for workers to participate in the evaluation task. A form with all the criteria could be created and shared via the MTurk system with a link and the answers would be interrogated on an Excel spread sheet at the same time as the criteria were being judged.
Based on the prior experience of a livingroom layout design experiment (Wu et al. 2014b), in the evaluation task, participants were paid $0.25 in the pre-experiment. However considering that participants were required to judge 10 concepts, and for each concept they needed to evaluate 10 criteria (in total one worker had to answer 100 questions). As a result the authors decided to increase the payment to $0.50.
To avoiding participants cheating in the evaluation process (i.e., giving scores randomly), a CAPTCHA (Completely Automated Public Test) image was used. Also, the authors could easily detect this kind of random answers by the Excel spread sheet, so they were eliminated and not used in any further analysis. The next section discusses how designs were combined after the evaluation of the 1^{st} generation designs as well as the final design and evaluation results.

4 DESIGN COMBINATION AND RESULTS

4.1 1st Generation Layout Design and Evaluation Results

Based on the design process from the experiment workflow, in the first stage, participants submitted 10 approved 3D kitchen layout designs named from G1.1 to G1.10 (in figure 4). Then workers evaluated them on the basis of 10 criteria (e.g., easy to move around, relative location of key objects, etc.) with the scores ranging from 1 to 5. In total, 36 approved evaluation results were collected.
As a result, in terms of the layout design ranking, the score of the sum of the average for each criterion was ranked (1) (S_{G1} means the average score of each criterion for the 1^{st} generation designs, S_{S1} means the sum of all evaluation scores for one design, N means the number of participants who evaluated design. To get an average score the results were summed and divided by 10 (i.e., there are 10 criteria for each evaluation).

$$S_{G1} = (S_{S1} / N) / 10 \quad (1)$$

The results show that the top ranked designs from generation 1 are: G1.7 (3.755 scores), G1.5 (3.664 scores), and G 1.10 (3.536 scores) (in table 1). So these three designs from the 1^{st} generation were selected to be combined in the next step in the hope of producing better designs.

4.2 Design combination and evaluation results

4.2.1 1st generation designs combination

Once the best three designs from the 1st generation were selected, the combination process started. Previously from the 2D sketch experiment (Yu & Nickerson 2011) it had been reported that better designs come from combinations, it was assumed that in 3D design experiment, then similar results would probably emerge. Consequently, the best three 1^{st} generation designs were combined by Turkers (i.e., workers on MTurk) (link of the task description: http://tinyurl.com/kc3979a).
The combination process is illustrated as figure 5 below. G1.7 was combined with G1.5 (C1: G2.1, G2.2 and G2.3); G1.5 with G1.10 (C2: G2.4, G2.5 and G2.6); G1.7 with G1.10 (C3: G2.7, G2.8 and G2.9) ('C' means combination).

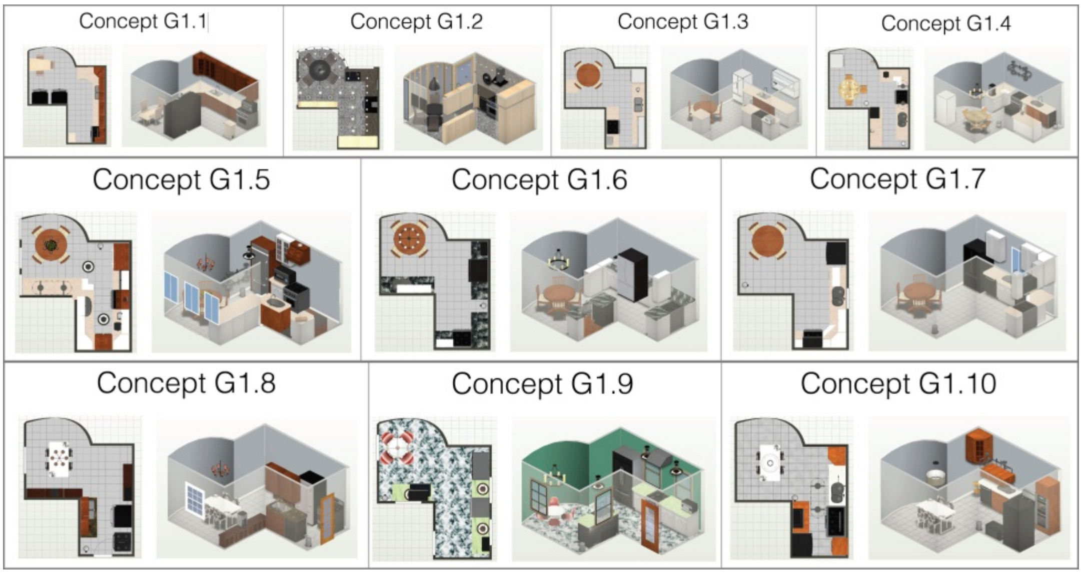

Figure 4. Ten 1st generation layout designs, link for high quality image

Table 1. Scores for the 1st generation designs

Generation 1 Evaluation				
	Total	Average	Total of	36 Answers
G1.1	1221	3.392		9 Brazilians
G1.2	1217	3.380		8 Indians
G1.3	1163	3.231		1 Irish
G1.4	1175	3.264		18 Americans
G1.5	1319	3.664	Average Age	32.80
G1.6	1131	3.142		
G1.7	1352	3.755		
G1.8	1140	3.167		
G1.9	1117	3.105		
G1.10	1273	3.536		

Table 2. Scores for the combination designs

Scores for G1.7 and G1.5				
	Total	Average	**Total of**	**16 Answers**
G2.1	**567**	**3.544**		6 Indians
G2.2	565	3.531		10 Americans
G2.3	511	3.194	**Age Average**	32.87
Scores for G1.5 and G1.10				
	Total	Average	**Total of**	**15 Answers**
G2.4	548	3.650		6 Indians
G2.5	**564**	**3.760**		9 Americans
G2.6	518	3.450	**Age Average**	30.20
Scores for G1.7 and G1.10				
	Total	Average	**Total of**	**15 Answers**
G2.7	547	3.647		5 Indians
G2.8	**577**	**3.847**		8 Americans
G2.9	568	3.787		2 Russian
			Age Average	28.00

4.2.2. Combination designs evaluation

From the combination process, each pair created three combination layouts. Because only one of those three designs for each pair would be selected for the next final evaluation stage, an evaluation task for them was published on MTurk which applied the same evaluation method – 5-Point Likert Scale as in the 1st generation evaluation stage. From table 2 it can be seen that for each pair, the winners are $C1_B$: G2.1, $C2_B$: G2.5 and $C3_B$: G2.8 (‘$_B$’ means the best).

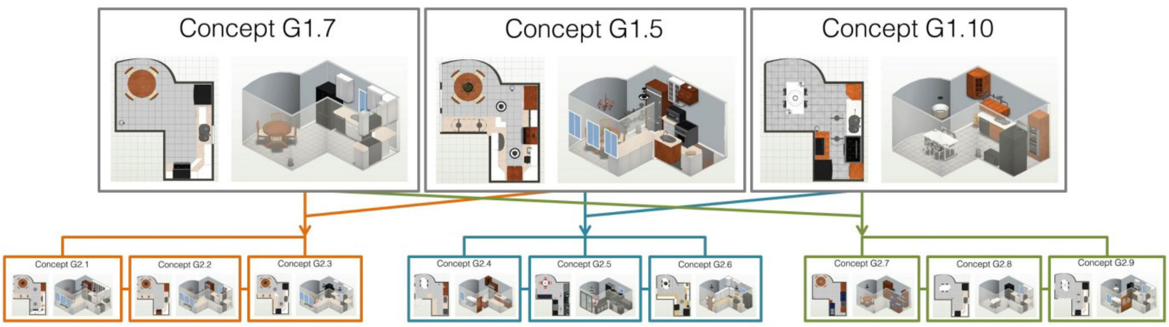

Figure 5. Layout Combination Progress

5 DISCUSSION

In this section, the results of this 3D kitchen layout design experiment are compared with that of the 2D living room layout design experiment (Wu et al. 2014a; Wu et al. 2014b). However, before the experiment execution and evaluation, differences between them have emerged.

Although the cDesign framework provides a systematic and integrated methodology for crowdsourcing's application in a design domain, it needs to be applied according to the nature of the design task (i.e., 2D design or 3D Design) specifically. Firstly, design tools in 2D design tasks and 3D design tasks are different. In the livingroom layout design experiment (Wu et al. 2014b) and the children's chair design experiment (Yu & Nickerson 2011), an online 2D drawing tool "Google Drawing" was required for the use of participants in order to create designs. However in the 3D kitchen design experiment, workers had to use a 3D design tool "Autodesk Homestyler" to build up 3D models for the layout. Secondly, the payment for participants was obviously different. In the kitchen modelling experiment, four approved results were collected during 24 hours by payment of $1.00. However in the 2D drawing task, 20 approved layouts were received in the same time by the same payment. The reason for this significant difference is assumed that the 3D design process is more complicated and difficult than the 2D.

In terms of the comparison of the design, after the design combination process, the quality of the combined designs was improved enormously (Yu & Nickerson 2011). The scores of the best designs in Table 1 and Table 2 are illustrated in Figure 6 by means of the lowest and the highest scores in the combination generation where it can be seen that 2nd generation results (pink) are all higher than those of the 1st generation (blue). Additionally, the average score of the best designs in the combination generation (3.717) is also higher than those of the 1st generation (3.652), which means the quality of designs did increase in the later generation.

The crowd's evaluation was validated by inspection of all the generated layouts by two professional architects. The architects confirmed that the quality of generation two (combined designs) was superior to generation one, and selected design G2.1 as the best overall. This judgement by expert practitioners confirms that the crowd's ability to evaluate designs (verifying that the best features had been effectively combined).

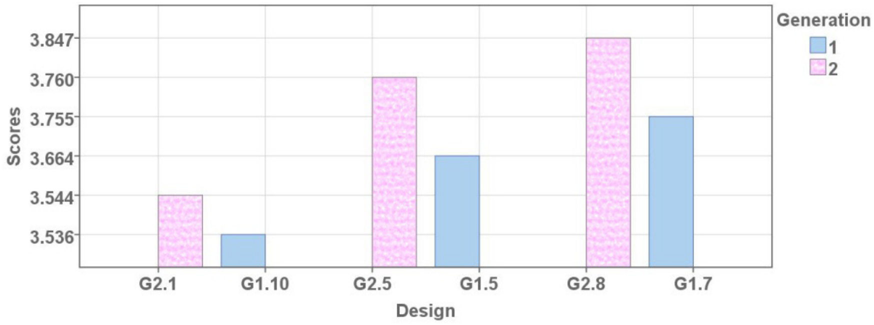

Figure 6. Scores of the best 3 designs from generation 1 and the generation 2 (combined designs)

6 CONCLUSION, LIMITATION AND FUTURE WORK

This paper has demonstrated the use of a 3D cloud based CAD tool to support an iterative crowdsourced design and evaluation tasks. The results suggest that this type of tool (i.e., open, cloud based CAD) is appropriate for both 2D and 3D crowdsourced design tasks. Furthermore, the cDesign framework presented in this paper has proved flexible enough to support 3D design tasks. However, because the number of the experimental results especially in the design combination stage was relatively limited the results can only weakly support the assertion that the use of the crowdsourced design method and strategy (i.e., HBGA) is effective for 3D work. In future work, more 3D design tasks need to be posted on the crowdsourcing platform to broaden the data from designs created using the cDesign framework. Also the choice of parameters required to optimise the quality of the crowdsourced 3D design needs further investigation.

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REFERENCES

Amabile, T., Creativity in Context: Update to the Social Psychology of Creativity, Westview Press, June 7, 1996.

Anon, TaskChina. Available at: http://weike.taskcn.com/ [Accessed February 10, 2014].

Bao, J., Sakamoto, Y. & Nickerson, J., 2011. Evaluating Design Solutions Using Crowds. In Seventeenth Americas Conference on Information Systems, August 4th-7th, Detroit, Michigan.

Brabham, D., 2009. Crowdsourced advertising: how we outperform Madison Avenue. Flow: A Critical Forum on Television and Media Culture.

Chilton, S., 2009. Crowdsourcing is radically changing the geodata landscape: Case study of OpenStreetMap. 24th International Cartographic Conference.

Eickhoff, C. & Vries, A. de, 2012. Increasing cheat robustness of crowdsourcing tasks. Information Retrieval, 16(2), pp.121–137.

Fischer, G., McCall, R. & Morch, A., 1989. Design environments for constructive and argumentative design. In Proceedings of the SIGCHI conference on Human factors in computing systems Wings for the mind - CHI '89. New York, New York, USA: ACM Press, pp. 269–275.

Fukuda, T. et al., 1997. Networked VR System : Kitchen Layout Design for Customers. In Proceeding VRML '97 Proceedings of the second symposium on Virtual reality modeling language. pp. 93–100.

Haklay, M. & Weber, P., 2008. Openstreetmap: User-generated street maps. Pervasive Computing, IEEE, pp.12–18.

Hogue, C., 2011. Crowdsourcing for science. Chemical & Engineering News.

Horton, J. & Chilton, L., 2010. The labor economics of paid crowdsourcing. In Proceedings of the 11th ACM conference on EC'10, June 7–11. Cambridge, Massachusetts, USA, pp. 209–218.

Howe, J., 2006. The rise of crowdsourcing. Wired magazine, (14), pp.1–5.

Jeppesen, L.B. & Frederiksen, L., 2006. Why Do Users Contribute to Firm-Hosted User Communities? The Case of Computer-Controlled Music Instruments. Organization Science, 17(1), pp.45–63.

Kittur, A., Chi, E.H. & Suh, B., 2008. Crowdsourcing for Usability : Using Micro-Task Markets for Rapid , Remote , and Low-Cost User Measurements.

Kittur, A., Chi, E.H. & Suh, B., 2008. Crowdsourcing user studies with Mechanical Turk. Proceeding of the twenty-sixth annual CHI conference on Human factors in computing systems - CHI '08, p.453.

Kosinski, M. & Bachrach, Y., 2012. Crowd IQ: Measuring the intelligence of crowdsourcing platforms. In WebSci '12 Proceedings of the 3rd Annual ACM Web Science Conference, NY, USA. pp. 151–160.

Kozinets, R. V., Hemetsberger, a. & Schau, H.J., 2008. The Wisdom of Consumer Crowds: Collective Innovation in the Age of Networked Marketing. Journal of Macromarketing, 28(4), pp.339–354.

Little, G. et al., 2009. TurKit : Tools for Iterative Tasks on Mechanical Turk. IEEE Symposium on Visual Languages and HumanCentric Computing VLHCC, (Figure 1), pp.252–253.

Liu, T. & Yang, J., 2011. Crowdsourcing with all-pay auctions: A field experiment on Taskcn. ASIST 2011, October 9-13, New Orleans, LA, USA. [Accessed June 22, 2013].

Nomura, J. et al., 2001. Virtual reality technology and its industrial applications. Annual Reviews in Control, 25, pp.99–109.

Osborn, A.F., 1957. Applied imagination; principles and procedures of creative problem-solving, Published by Scribner's.

Pahl, G. et al., 2007. Engineering design: a systematic approach, [Accessed October 3, 2014].

Paolacci, et al., 2010. Running experiments on amazon mechanical turk. Judgment and Decision Making, 5(5), pp.411–419.

Pugh, S., Total Design: integrated methods for successful product engineering, Addison-Wesley Pub. Co., 1991.

Stewart, O., et al., 2009. Designing crowdsourcing community for the enterprise. ACM SIGKDD Workshop on Human Computation, pp.50–53.

Wang, A., Hoang, C.D.V. & Kan, M.-Y., 2012. Perspectives on crowdsourcing annotations for natural language processing. Language Resources and Evaluation, 47(1), pp.9–31.

Whitfield, R. et al., 2002. Distributed design coordination. Research in Engineering Design, 13, pp.243–252.

Wu, H., Corney, J. & Grant, M., 2014a. Crowdsourcing Measures Of Design Quality. In 34th Computers and Information in Engineering Conference (CIE).

Wu, H., Corney, J. & Grant, M., 2014b. Relationship between quality and payment in crowdsourced design. In Proceedings of the 2014 IEEE 18th International Conference on Computer Supported Cooperative Work in Design (CSCWD). Ieee, pp. 499–504.

Yang, J., et al., 2008. Competing to Share Expertise: The Taskcn Knowledge Sharing Community. In ICWSM.
Yochai Benkler, 2006. The wealth of networks: How social production transforms markets and freedom. Yale University Press.
Yu, L. et al., 2011. Cooks or cobblers?: crowd creativity through combination. CHI 2011, May 7–12, Vancouver, BC, Canada.
Yu, L. et al., Generating creative ideas through crowds: An experimental study of combination. In Thirty Second International Conference on Information Systems, Shanghai 2011.
Yu, L. et al., 2011. Feature selection in crowd creativity. Foundations of Augmented Cognition. Directing the …, pp.383–392. [Accessed June 25, 2013].