

Crowdsourcing

Theoretical framework, computational environments and design scenarios

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Abstract. *Crowdsourcing is a new concept for breaking with the traditional hierarchical model of collaborative design. Crowdsourcing is based on web-based contributions of individuals in a decentralized digital environment that supports the sharing of opinions and creative ideas. This article develops the concepts and issues associated with the possibility of crowdsourcing design as well as discussing its relationship to prior developments of media environments for collaborative design. Three scenarios for crowdsourcing in architectural design are developed as a basis for considering the requirements for the design and function of crowdsourcing media environments in architectural design.*

Keywords. *Digital design; social network; creative design; collaborative design; crowdsourcing; crowdsourcing design.*

INTRODUCTION

In recent years the term 'collective intelligence' and its potential relationship to 'collective design' has appeared widely over a broad spectrum of scientific, sociological and design studies. In order to adapt the culture of design to emerging models of social networking as a potential medium for collectively creation of design solutions there is a need to explore and understand the potential of 'crowdsourcing' to function as a social medium for design. The following paper makes an attempt to define the theoretical and operative sources of concepts as well as the developmental issues that might promote crowdsourcing as the basis for collective design as an open-source design environment.

CROWDSOURCING: THEORY, CONCEPTS, ISSUES

Collective intelligence is one of the seminal foundational concepts of this emerging field. It has been described as 'universally distributed intelligence' and as the 'universality of intelligence' (Lévy, 1997). In 'team-based collective intelligence groups' the participants usually focus on achieving a predictable and well-defined outcome. The effectiveness of such team-based groups in distributed space is usually related to the limitation of the number of participants and the strategies of interaction. New principles were later introduced in order to overcome such limitations; the provision of command and control structures were established and supported by standards, norms and shared language to support the 'interoperability' of collective knowledge.

While psychological studies of collective intelligence were based on observations of human team behavior, other studies were inspired by evolutionary processes in nature in which shared intelligence is based on such biological drives as survival and reproduction (Lévy, 1997). Most well known among these were those terms such as 'swarm intelligence', an emerging model that was inspired by the behavior of insect societies in nature. Computational models and systems classified as 'swarm computing' were inspired by such instinctive biological behavior.

According to Lévy, collective intelligence can be characterized by the following three concepts: universal distribution of intelligence, constant enhancement, and coordination in real-time for effective mobilization of skill. Due to the development and popularity of the World Wide Web and information technologies, the Internet today provides a media environment that accommodates these principles. Autonomous individuals in a scale-free decentralized environment can freely communicate and interact. The effect of the 'wisdom of the crowd' started to be realized and supported by interactive communication media enabled by the Internet. Among early examples of the exploitation of Internet media 'crowd wisdom' was evident in the study of statistical phenomenon in areas such as stock markets, political elections, etc. (Surowiecki, 2004).

With the development of Web-based communication in providing means for information exchange of both textual and graphical information, the crowd-model has emerged as a useful model for use in decentralized business models. With the model Web-based commercial companies could interact with the total body of consumers rather than with specific group members. This phenomenon is termed 'Crowdsourcing'. The difference between crowdsourcing and ordinary outsourcing is that the task or the problem to be solved can be openly distributed to a body of unknown potential contributors rather than to specific collaborators.

Crowdsourcing is a new concept for breaking with the traditional hierarchical model of collaborative design. Crowdsourcing is based on web-based

contributions of individuals in a decentralized digital environment that supports the sharing of opinions and creative ideas. Thus the design of such media environments is among the enabling factors in crowdsourcing.

Crowdsourcing, or mass participation, has become an emerging model for "online, distributed problem-solving and production" (Brabham, 2008). The model has potential for solving scientific problems as well as sourcing new ideas for creative arts such as music and photography. It has been applied to e-business exploiting a massive crowd of online users, for example, in 'Threadless' consumers propose creative new ideas for T-shirt design (<http://www.threadless.com>); in 'iStockphoto' photographers contribute photographed images for an online library of photos (<http://www.istockphoto.com>); 'InnoCentive' connects research organizations with a global community of potential scientific advisors in order to support innovation (<http://www.innocentive.com>); and 'TopCoder' organizes competitions to encourage creative software development (<http://www.topcoder.com>).

Despite of the immense interest in adopting crowdsourcing in design, there is a current lack of adequate conceptual understandings, formal guidelines, and supporting Web-based techniques that can effectively facilitate the potential of crowdsourcing in design.

FROM COLLABORATIVE DESIGN TO CROWDSOURCING DESIGN

Collaborative design is relatively well understood in the literature, and is characterized by small-scale, carefully structured, professional design teams. However, while individual designers are generally conducting reflective practices on their own, the complexity of the design projects and the influence of a global economy have created demands to find solutions for extended needs and changed scale and modes of design towards the adoption of new collaborative models addressing the needs of global practices. Lahti et al. (2003) define design collaboration as a process where designers dynamically com-

municate and work together, aiming to collaboratively establish design goals, search through design problem spaces, determine design constraints, and construct a design solution. While individual designers can creatively contribute to the development of design, collaborative design implies well-organized teamwork and negotiation that enable individual designer to effectively collaborate. In fact, design collaboration depends on collaboration with other designers within the discipline as well as collaboration with design experts across the discipline. Teamwork and negotiation processes are based on shared domain knowledge and both intra-disciplinary and inter-disciplinary expertise.

The increasing popularity of open-source online environments, which may include both social networking sites and other technically sound environments such as 3D virtual worlds, has significantly increased the participation of both design professionals and design novices in a wide range of design activities. Featuring design, modeling, communication and other tools that support online communities, 3D virtual environments may further suggest possibilities for the development of digital design environments for supporting crowdsourcing beyond current small-scale collaborative design scenarios (Merrick and Gu, 2011).

Open-source online environments are already a recognized platform for collective intelligence that emerges from collaboration and competition among large numbers of individuals. Collective intelligence games such as “I Love Bees” (McGonigal, 2008), and applications such as NASA’s “Clickworkers” (Romero, 2009), have demonstrated the capacity of collective intelligence to solve complex problems (Maher et al., 2010). Redirecting such collective intelligence principles in order to accommodate complex design is one way of approaching the design problem of crowdsourcing design environments. Beyond small-scale collaborative design scenarios, crowdsourcing design has the potential to enable large-scale, interdisciplinary participation, representing different levels of expertise, in addressing increasingly complex and challenging design

tasks and in providing creative solutions. In comparison to collaborative design, crowdsourcing design can attract a large number of unknown potential participants representing different levels of domain-specific knowledge, interdisciplinary knowledge and expertise who may be interested and motivated to contribute to design.

Understanding the impact of emerging technologies on novel representational media, computational methods, and digital processes (Oxman, 2006) is critical to the development of future media for crowdsourcing design. Beyond these problems that affect the design of crowdsourcing design environments, other problems such as authorship are central in any research on crowdsourcing design. The understanding and formulation of such complex operative and institutional issues related to crowdsourcing design are equally critical. However at this very early stage in the development of designing crowdsourcing media it is essential to begin with providing a theoretical and developmental foundation. Among other issues, what is required is the clear definition of the principles of operative and technological requirements of online environments that can support design activities suitable for crowdsourcing and provide design environments enabling crowd participations. Only through the establishment of such enabling conditions will we be able to foster, motivate and exploit crowd wisdom in design.

CROWDSOURCING DESIGN: THEORETICAL FRAMEWORK

While decision-making and problem-solving processes in crowdsourcing can be guided by statistical results, design as a cognitive activity is characterized as unique thinking processes. Furthermore, in contradiction to the statistical or optimal outcome that can be associated with the non-hierarchical collective social intelligence of the crowd, design is a task domain that focuses on unique and specific representational and operative skill. As such it requires specific knowledge and skill-media that are based on accepted representational methods and pro-

cesses. Importantly, the success is not only based on these accepted representational methods and processes but also on the unique body of disciplinary knowledge.

In order to develop a theoretical framework for crowdsourcing in design a review of the issues and principles is presented below followed by a critical analysis of the conceptual, technical and operative requirements of crowdsourcing design, with references to their impact on the design discipline. Finally we employ these theoretical principles in the postulation and analysis of various scenarios for the development of media environments suitable for crowdsourcing design. While other aspects of design such as the business plan and user motivation are also of paramount importance, our focus here is upon the design principles of web-based environments that may enhance and support crowdsourcing design.

CROWDSOURCING DESIGN: SCENARIOS

Virtual worlds are complex, multi-faceted technologies, which may be an ideal base and point of departure for exploring media frameworks for crowdsourcing design. There are many facets of virtual worlds that may make them relevant for adaptation to future media environments suitable for crowdsourcing design. These include, among others, components of artificial intelligence, communications protocols, network organizational structure, graphical simulation tools, design and modeling tools, persistent object-oriented infrastructure, principles of economy and governance, and technologies of user presence and interaction (Bartle, 2004). Recent studies and applications (Maher et al., 2006; Rosenman et al., 2006) have demonstrated that the combination of design, modeling and communication tools along with incorporated artificial intelligence makes virtual worlds suitable platforms for supporting collaborative design, including human-human collaboration and human-computer co-creativity. Because of the close relationship between design, collective intelligence and virtual worlds, there appears a strong possibility of crowdsourcing design

in 3D virtual worlds. Virtual worlds are also coming to be recognized as a platform supporting general crowdsourcing in order to enable a very large number of individuals to develop potential collective intelligence.

Various potential technical approaches and devices to crowdsourcing design such as open-source social networking, open-source modeling, parametric scripting, and generic open-source prototyping will be evaluated through the illustrations of series of design scenarios. The following criteria were selected as critical issues in developing and evaluating crowdsourcing media environments for design. These will be introduced, discussed and presented in relation to the presentation and demonstration of the scenarios. These criteria were adapted from Maher et al.'s 'conceptual space of large-scale collective design' (2010). The 'type of representational media' refers to different technologies that facilitate various digital representations of the design for supporting different design processes, and the 'type of communication modes' refers to different ways of co-authoring, co-editing and co-sharing the digital design representations in terms of synchronous and/or asynchronous communication, in order to support crowdsourcing design.

In order to explore these foundational issues, we propose and consider three selected scenarios that appear to demonstrate promise in realizing certain of the potential past works in social networking sites as well as 3D virtual worlds in collaborative design and adapting them to new media environments for crowdsourcing design.

Design scenario I: Open-source social networking

A social network is a social structure made up of individuals or organizations called 'nodes', which are connected by one or more specific types of interdependency, such as friendship, kinship, common interest, financial exchange, dislike, sexual relationships, or relationships of beliefs, knowledge or prestige. Open-source design scenario explores the use of common social networking technologies

(i.e. Blogging, Facebook, Wiki, etc.) for supporting crowdsourcing design. It proposes to exploit and integrate existing media in a new consolidation that potentially amplifies communication in design.

Although some social networking sites also provide synchronous communication tools, the main communication mode in social networking is asynchronous and is based on shared discourse on textual and image-based representational media that can also include sound and video (i.e. Youtube, etc.). For example, Facebook (<http://www.facebook.com>) allows users to post content to either their own or others' 'wall' in the form of text, images or embedded video content. Comments can be made which directly relate to the posted content. There are a number of communication methods within Facebook, including private messaging, posting on the 'wall' for others to see and comment, as well as an instant messaging feature which allows real-time synchronous communication between users which are logged on. Within groups or 'events' in Facebook, it is possible for users who are not 'friends' (non-group members) to communicate with each other via commenting on content posted.

Twitter (<http://www.twitter.com>), is a different type of popular social networking. In terms of the representational media, 'tweets' are short text based descriptions, and they can be link to other websites or pages within Twitter. When communicating in Twitter, users can group posts together by topic or type by the use of hash tags – words or phrases prefixed with a #. Similarly, the @ sign followed by a username is used for mentioning or replying to other users. If a user wants to repost a message from another Twitter user, and share it with their own followers, they use the 'retweet' function symbolized by 'RT' in the message. In this way, Twitter posts can directly link to relevant content on other pages.

Departing from those that are more socially oriented is Wikipedia (<http://www.wikipedia.com>). It is a web-based, collaborative, multilingual encyclopedia project supported by the non-profit Wikimedia Foundation. It is widely recognized for the non-expert-driven style of the encyclopedia building mode

and the large presence of non-academic content. Information on Wikipedia is represented in the form of referenced text articles, which can be accompanied by relevant images and links to other sources of information. Keywords within Wikipedia are linked to more information on that topic within Wikipedia. The content of Wikipedia is entirely user generated, where both the information and legitimacy of the information depend on the mass participation of users who access it. In departure from the style of traditional encyclopedia, Wikipedia employs an open, "wiki" editing model. Except for a few particularly vandalism-prone pages, every article may be edited anonymously or with a user account, while only registered users may create a new article. No article is owned by its creator or any other editor, or is vetted by any recognized authority, rather, the articles are agreed on by consensus. A 'WikiProject' is a place for a group of editors to coordinate work on a specific topic. The discussion pages attached to a project are often used to coordinate changes that take place across articles.

To focus and direct the use of these social networking sites for design purposes, the development of the communications format becomes of prime importance. Protocols for naming, classifying, adapting, varying and saving alternative design ideas and design representations become important in the development of the design interface. Design evaluation and selection such as voting and other more detailed performative evaluation techniques might be employed.

This approach to an eclectic, multi-media design platform for crowdsourcing design might be considered to provide an open collage-like approach to design in the visual sense. It would probably be possible to adapt such an approach to integrated performative evaluation, e.g. as in various performance indicators in architectural design. The great developmental challenge is the successful toggling together of various media in support of important and highly characteristic design processes and tasks.

Table 1 highlights the characteristics of 'Open-Source Social Networking' for supporting crowd-

Table 1
Types of communication
modes and representational
media of Open-Source Social
Networking.

Criteria	Descriptions
Types of communication modes	The main communication mode is asynchronous
Types of representational media	Textual and image-based design representational media that can also include sound and video

sourcing design in terms of the two criteria ‘type of communication modes’ and ‘type of representational media’.

Design scenario II: Open-source modeling

The Open-source Modelling scenario focuses on 3D design through modelling in web-based online environments. It is far more task-specific than the first scenario and enables the shared manipulation of the design. By comparison to the first scenario that is by-definition more conceptual and suitable to conceptual design and brainstorming, this second scenario is highly suitable to specific design tasks, and collaborative design in more advanced stages of the design process through user-generated 3D models. It could also be a means to access solutions to particular recurring problems in architecture, e.g. complex plan development, complex geometries, etc. The term ‘user-generated content’ entered mainstream usage during the new millennium having arisen in web publishing and new media content production circles. Its use for a wide range of applications, including news, gossip, general problem processing and research, reflects the expansion of media production through web-based technologies that are accessible and affordable to the general public. In addition to these technologies, user generated content may also employ a combination of open source, free software, and flexible licensing or related agreements to further reduce the barriers to content and skill discovery, building and sharing. User-generated 3D models – the ‘user-generated content’ through 3D modelling in web-based online environments – differ from general ‘user-generated content’ such as Wikipedia entries by directly ena-

bling shared manipulation of the design either synchronously or asynchronously.

For example, in Second Life (<http://www.secondlife.com>) and other 3D virtual worlds or 3D network game environments, the interface is an animated ‘avatar’ immersed in an online 3D world. For design, due to the editable nature of some elements of this virtual world, it is possible for 3D explorable representations and manipulations of the design. The concept of online design collaboration and participation using the virtual worlds has been explored by ‘Studio Wikitecture’ (<http://studiowikitecture.wordpress.com>). Studio Wikitecture is an open designgroup, composed of a diverse range of individuals from varying disciplines, interested in exploring the application of an open-source paradigm to the design and production of both real and virtual architecture and urban planning. Using 3D virtual world platforms such as Second Life, Opensim (<http://www.opensimulator.org>), RealXtend (<http://realxtend.wordpress.com>), the group has been conducting ‘Wikitecture’ projects to explore the protocols and procedures necessary to harness a group’s collective intelligence in designing architecture. In other words, in much the same way as Wikipedia enables a loose, self-organizing network of contributors to collaborate on textual and graphical content creation, the Studio Wikitecture group has been using these projects to develop and trial the manner by which a group of geographical disperse individuals can come together to share ideas, edit the contributions of others, and to determine the effectiveness of proposed design iterations.

Not only is this scenario task-specific, but its generality and appeal depends very much on the

Table 2
Types of communication
modes and representa-
tional media of Open-Source
Modeling.

Criteria	Descriptions
Types of communication modes	The communication mode can be either synchronous or asynchronous
Types of representational media	3D geometric design representational media such as digital models

attractiveness and flexibility of the design environment which is provided, its built-in support, resources and knowledge. This is the case with all three of the scenarios. However, here the key to open participation is prioritized by a certain level of knowledge and skill, i.e. 3D model creation and sharing. Given that this contributes a certain level of the 'gated' to the outsourcing, this is a very important factor to consider with respect to motivation. In addition, 3D models as the representational media would potentially provide for detailed analyses, etc.

Table 2 highlights the characteristics of 'Open-Source Modeling' for supporting crowdsourcing design in terms of the two criteria 'type of communication modes' and 'type of representational media'.

Design Scenario III: Open-source generic prototyping

The open coding and scripting of generic design prototypes can be another important feature for supporting crowdsourcing design. Similar to Arduino (<http://www.arduino.cc>), an open-source electronics prototyping platform for creating interactive objects or environments, generic prototyping platforms for design can be developed.

Generic prototyping are suggested as a new way to support experimentation and creation of generic design solutions for adaptation and change in fields such as performance and sustainable design. Beyond the demands of the interface design of Scenario II, here the problem-definition becomes highly significant. One can conceive of generic prototypes as being highly domain specific typologies such as architectural types, or geometric types. Within such well-defined areas of typological problem definition, techniques such as parametric design can func-

tion as the medium for open-source programming of potential solutions to generic prototypes.

Parametric design technology is one example that can support this approach. It is a design concept that can support generic prototyping. Parametric design focuses on the representation and control of the relationships between objects. It supports the creation of complex parametric models of design (Woodbury et al., 2007). Using parametric design tools these can be adapted and modified to different situations by performative models of design (Oxman, 2009). In parametric design systems, design representations can be shared and communicated through both scripting and modelling (Aranda and Lasch, 2008). Aish (2005) proposes two levels of algorithmic thinking. The first level explores geometric subtleties in which equations are established to describe modeling relationships; the second level supports ideas of consistency or controlled unpredictability in large data sets, that is, it supports emergence of unexplored data in previously unexplored conditions.

Parametric scripting has been proposed to support collaborative design through modules (Davis et al., 2011) and is an important potential scenario in supporting crowdsourcing in architectural design. Web sites and forums that share parametric scripts and modules have become very popular among the parametric design community. Parametric scripting may become an interesting medium for crowdsourcing in design within the community of script-capable parametric designers including both professionally trained designers and non-professional designers who are appeal to or familiar with this new design medium. Collaborative design activities in parametric scripting can be supported

Criteria	Descriptions
Types of communication modes	The main communication mode is asynchronous
Types of representational media	3D geometric (through parametric modelling) and algorithmic (through parametric scripting) design representational media

Table 3
Types of communication modes and representational media of Open-Source Generic Prototyping.

through the co-authoring, co-editing and co-sharing of parametric scripts and modules. More importantly, the scripting environments as the new design medium enable these non-professional designers to participate in design activities, who might not be able to contribute to design other wise, because of their lack of knowledge and skills in mastering other types of architectural communication and representation. It would also potentially serve to create an open-source bank of architectural scripts to be shared within and beyond the profession, and might become a significant force for the technological development of the profession.

Table 3 highlights the characteristics of 'Open-Source Generic Prototyping' for supporting crowdsourcing design in terms of the two criteria 'type of communication modes' and 'type of representational media'.

CONCLUSION

This paper has explored the potential and significance of the concept of crowdsourcing in design. Historically this new concept has conceptual foundation and performance evidence in the evolution of the concepts and phenomena of 'collective intelligence' as well as the theories and practices of 'collaborative design'.

Given the growth of the role of the web-based online environments, including various social networking sites and 3D virtual worlds, in all aspects of our daily life, it would appear that the powerful democratic and socializing forces of communications media will eventually have an impact on the design discipline. We have proposed that one way in which web-based online environments may be

adapted to the exploitation of social intelligence in design is by the creation of media that can support open, collective, distributed design processes.

In considering the enabling conditions of crowdsourcing design we have based our proposals upon prior work in the related areas of virtual environments and in collaborative design. Within the framework of this background of prior work, we have developed three scenarios for crowdsourcing in architectural design. Each of these scenarios has been presented schematically and presents its intrinsic issues in its potential contributions to its application as a medium supporting crowdsourcing design. With this important first step, it is possible to further explore the following issues, which are the future directions of our research:

- Type of communication modes.
- What are the types of communication modes that can support crowdsourcing design? What are the alternatives? How can they be evaluated and implemented?
- Type of representational media.
- Generative processes are key characteristics in design. What kinds of representational media can support generative processes in crowdsourcing design? How can generative processes be implemented in a crowdsourcing environment?
- Structure and dynamics of the crowd.
- Who is the crowd made up of, and how to formulate the suitable crowd dynamics for effective crowdsourcing design?
- What types of organizational strategies, structure and control can support the different dynamics in crowdsourcing design?

- How can disparate and distributed individuals share a language and format that enables them to act collectively in design to propose, develop, evaluate and refine design solutions?

While this research work is preliminary in nature, we believe that crowdsourcing design as an emerging field is of great potential to the future of the profession.

ACKNOWLEDGEMENTS

The authors acknowledge the contributions of Darin Phare, a Research Higher Degree student, and Matthew Boyle, a former Summer Scholarship Student both from the School of Architecture and Built Environment at the University of Newcastle, Australia, for collecting and reviewing parts of the sources that form the background sections of this article.

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