Scaling up: From Individual Design to Collaborative Design to Collective Design

Mary Lou Maher, Mercedes Paulini and Paul Murty
The University of Sydney, Australia

Abstract

This paper presents a conceptual space for collective design to facilitate development of design environments that encourage large scale participation in the next generation of challenging design tasks. Developing successful collective design starts by understanding how individual and collaborative design are supported with computing technology and then goes beyond collaborative design to structure and organize the design tasks so that people are motivated to participate. The analysis in this paper develops and illustrates several categories of motivation to be considered when implementing an environment for collective design.

1. Introduction

We are facing design challenges on a much larger scale as we become an increasingly global and technological society. Our design solutions not only need to respond to the needs and desires that may be included in a specific design brief, but they also need to be environmentally sustainable, attractive to multiple cultural groups, adaptable as technology changes, and intuitive to potential users. In Cradle to Cradle, McDonough and Braungart [1] argue that design for environmental sustainability has lost its way by focusing on reducing the impact of our designs on the environment, and advocate designing for reuse of natural resources when a product is no longer required. Tim Brown from IDEO proposes that designers cannot meet all of these challenges alone[1]. Both of these accounts, and a growing number of others, propose that we need to rethink design and extend the

[1] http://www.ted.com/talks/tim_brown_urges_designers_to_think_big.html

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capability and responsibility of design to all people.

Many innovative World Wide Web developers of applications, including Amazon, Google, Second Life and Wikipedia, have successfully implemented novel uses of the internet for large scale communication and collaboration. These developments offer us the opportunity to reconsider designing as a vital role of collective intelligence. There are many examples of the collective construction of knowledge and collective problem solving on the WWW, including examples of collective creativity. Collective design can facilitate a more inclusive design process by designers and non-design specialists by motivating the broader community to participate in design thinking.

When we describe and study design cognition, we consider the characteristics of the designer and design processes with a focus on the individual's cognitive processes when responding to an ill-defined problem. We value creativity and ingenuity and study highly creative individuals in order to better understand and encourage these processes in others. When we study collaborative design, we consider the ways in which multiple perspectives from a group of designers with different backgrounds can be brought together to create a synergistic solution. We value the emergence of solutions that could not be seen by any individual. Recognizing that creativity takes place in a community, studies show how computer support can enable the influence of the community on individual creativity, referred to as collective creativity by Nakakoji, Yamamoto, and Ohira [2]. Recently, the use of the internet for encouraging collective intelligence on a large scale allows us to go beyond studying individuals or teams of designers. We now have the opportunity to encourage and study large scale participation from individuals that may or may not be qualified as designers with the potential for a very large number of contributions to produce results that go beyond the capability of a more carefully constructed team of designers.

This paper presents a conceptual space for large-scale collective design. A conceptual space defines the dimensions along which a class of artifacts is described. When we encounter a novel way of designing, such as collective design, our conceptual space is expanded. The precedent for this is the change in our conceptual space for computer-supported design when digital communication technologies were introduced to the design process, enabling computer-supported collaborative design. The conceptual space for computer-supported design started with an articulation of technologies that facilitate various digital representations of the design artifact that support synthesis, analysis, evaluation, prototyping, and other design processes. This conceptual space expanded to include technologies for communication and sharing models in order to support collaborative design. The conceptual space for collective design adds another dimension to include principles associated with motivation: requiring incentives and structures that motivate selected designers and others to participate in collective design.

2. A Conceptual Space for Collective Design

Collective design is a phenomenon that is possible because we can easily communicate and share ideas, digital models, files, etc. on the internet. Computational support for design started with support for a single designer, primarily by providing a digital model of the design description as the basis for visual feedback and analysis. The early systems, known as CAD, were developed to assist in developing design drawings, and then design models. Successful collective design should build on the developments in and studies of computing technology that have been the basis for successful individual design and collaborative design.

Use of CAD for design is the norm now and the technology has developed to incorporate an extensive range of modeling and virtualization capabilities. In parallel with these developments, groupware for computer-supported collaborative work has developed and access to the internet has become more common. Computational support for design has been extended to support communication via email and collaborative portals. CAD systems have also been extended to support versions and sharing among a distributed team of designers. Research in virtual design studios and computer supported collaborative design has led to new tools and studies of teams of designers using computational systems. Studies of computer-supported collaborative work for creativity, such as Farooq, Carro, and Ganoe [3], show how collaborative tools can better support the creativity of small groups by improving the awareness of ideas generated by members of the group.

The development of social networks based on easy to use interfaces and the emphasis on communication and contribution made possible by Web 2.0 technologies has enabled many passive internet users to become active participants: engaging in discussion forums, creating social networks, taking part in opinion polls and building online communities and portals of knowledge. These developments provide opportunities for designing to be shared among large numbers of people, extending beyond the designated design team; opportunities for collective intelligence and therefore, collective design.

The term collective intelligence is commonly used to characterize the phenomenon of large numbers of people contributing to a single project and exhibiting intelligent behavior. The phenomenon is not new but it is being defined and redefined as new *variations on the theme* are emerging on the Internet at an increasing rate. In general collective intelligence can be described along a continuum: from aggregating the knowledge or contributions of individuals, a kind of collected intelligence, through to collaboration among individuals with the goal of producing a single, possibly complex output as a kind of collective intelligence. Rather than thinking of collected intelligence and collective intelligence as two separate entities, we can view them as two ends of a continuum, as illustrated in Fig 1, where the degree of direct interaction between individuals and their contributions differs. Systems may lie anywhere along this continuum as they incorporate more or less collaboration.

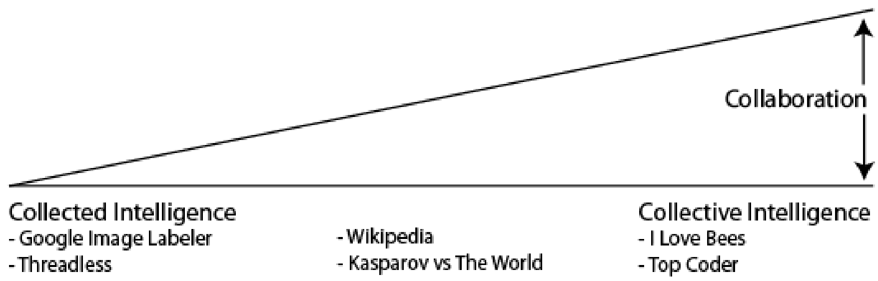

Fig. 1 The Group Intelligence Continuum: Collected Intelligence to Collective Intelligence.

Collected intelligence, on the left side of the continuum in Fig. 1, describes systems in which an individual contributes to a discrete task. The solution or outcome for each task is not synthesized with other solutions and therefore stands alone. The Image Labeler is an example of collected intelligence where each person contributes one or more labels to an image, but the labels need not be synthesized to a single coherent description of the image. The underlying principle behind collected intelligence lies with individuals providing the system with a single data item based on their own interpretation of the solution to a given problem. On the right side of Fig. 1, collective intelligence involves both collaboration and synthesis: individuals collaborate in the production of the solutions and individual solutions are synthesized for a synergistic solution. I Love Bees is a good example of collective intelligence where many individuals worked together to find and share more clues and to find the answer to the mystery.

Crowdsourcing is a term used to describe situations where the key to success lies in large numbers of individuals providing input at many stages of the process: In Threadless the individuals contribute the designs and vote for the best. In TopCoder the individuals contribute the code and vote for the best. Crowdsourcing can be used to achieve collected or collective intelligence. The significant feature of crowdsourcing is that the large numbers of people contributing are self-selected rather than preselected based on qualifications. According to Wolfe [4], crowdsourcing works when the number of participants is very large so that the small percentage of good ideas is a large number when collecting ideas or solutions, and the popularity of a solution is identified when voting.

As people and computers begin to work synergistically within systems, it becomes important to recognize the interaction between them and the role of collaboration in forming a collective intelligence. The concept that through interaction the whole can produce something greater than the sum of its parts, is a key idea in understanding collective intelligence.

One can conceptualize systems that enable collected and collective intelligence in design by looking at the progression of computer support for individual design through collaborative design to collective design as illustrated in Fig 2.

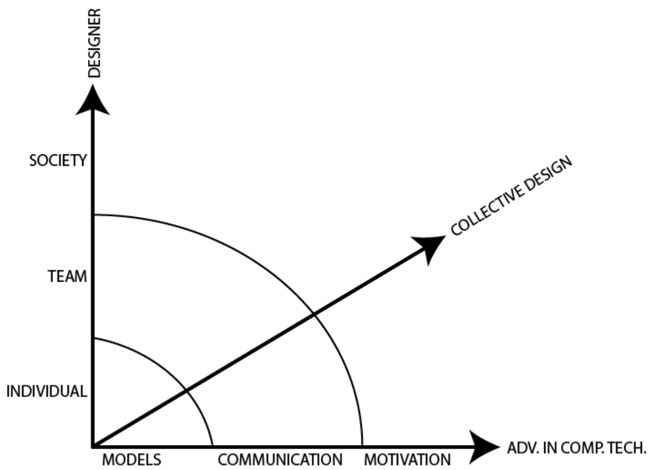

Fig. 2 Elements of Collective Intelligence in Design

The vertical axis represents the designer dimension. For the individual, the primary computational support for design is the digital model. For a team of designers, computer support for communication is a necessary component of successful collaborative design. To engage the broader population or society in design, motivation becomes critical. Popular participation is fundamental to the development of the unique social chemistry that precipitates collective intelligence in design. The role that advances in computing technology play in enabling individual, group and collective design is represented by the horizontal axis of Fig 2.

The conceptual space for collective design is illustrated in Fig 3. The three axes for defining the space are: Representation, Communication, and Motivation. Representation refers to the digital models and files that support visualization, analysis, synthesis, etc. The representation can be text, sketches, 2D models, 3D models, etc. Communication refers to the ways in which people can communicate during the design process, for example via blogs and email, and can be characterized as synchronous or asynchronous and as direct or indirect. Motivation refers to the principles of motivation and the way the participation in the design process is structured. The three axes are elaborated in the next sections.

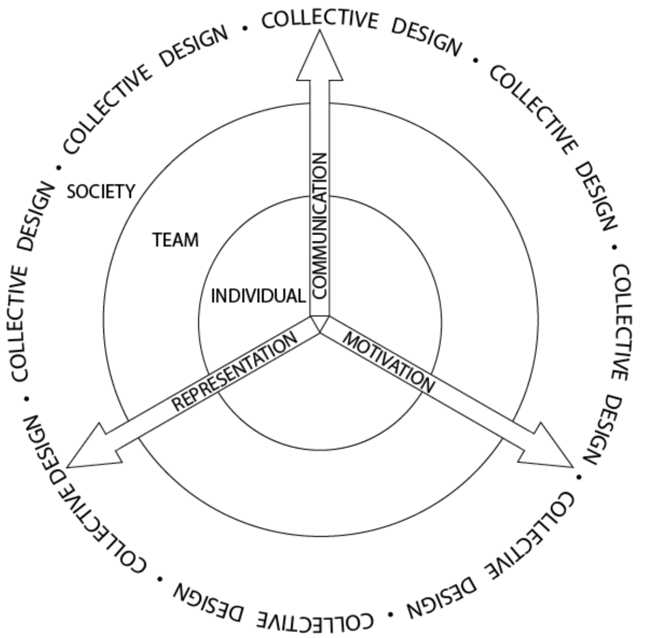

Fig. 3 Conceptual Space for Collective Design

2.1 The Representation Dimension

We use two categories to describe the representation dimension:

- *type* such as images, sketches, databases, audio, 2D drawings, 3D

models;
- *content* such as design problem, solution, and constraints.

A shared representation is required for collective intelligence, with or without collaboration. A (near) real-time external representation acting as shared memory is described in [2], considering the role of representation in reference to theories in philosophy and psychology. Halpin [2] asserts that the wide uptake of socially-generated content provides a community with the ability to influence each other for their greater collective success, and that Web 2.0 is a powerful facilitator for this. Since the individual has a limited and finite memory, they are able to record their thoughts onto the external environment of Web 2.0 and bring about social and collaborative creation and sharing of content. This is possible through intuitive interfaces, social networking tools and shared documents. Gruber [3] suggests in his paper on collective knowledge systems, that when the social web (Web 2.0) is combined with the semantic web, then collective intelligence is unlocked.

The first category for shared representation is the *type* of representation. Designers externalize their design ideas on the computer predominantly as structured and unstructured text, sketches, images, 2D/3D models, and more recently in databases. When one designer works on a problem alone, computer support for creating, editing, and sharing the representation relies on applications such as CAD, image processing software, and more recently 3D virtual worlds. This dimension of the conceptual space allows us to characterize the principles and alternatives for an external representation. Gul and Maher [4] studied how the type of external representation influences design cognition and the collaborative design process, showing that sketches facilitate more conceptual thinking than 3D models.

The second category of the shared representation is the *content*. In collaborative design, the participants share a description of the design problem, versions and components of the design solution, various constraints derived from domain knowledge, etc. Since designing involves creating new solutions to satisfy requirements and constraints, the shared representation is not static but is modified by the participants. Maher and Tang [5] describe the adaptation of the problem and solution spaces as a co-evolutionary process.

Levy [6] defines the role of a shared object in organizing efforts, such as the ball in a soccer game to coordinate movements. Heylighen [7] proposes a collective mental map, defined as an external, shared cognitive system. A collective mental map acts as an external memory accessed and contributed to by the collective. It represents problem states, actions and preferences for actions. In addition to components, relationships are relevant in a shared representation. The EWall project [8] is an example of a shared representation supporting brainstorming, decision-making, and problem solving. EWall supports individual and collective sense making activities by relating pieces of information in order to develop an understanding of a particular situation. The focus is on the explicit and implicit relations, shown in a spatial arrangement for collaborative use.

2.2 The Communication Dimension

We use four categories to characterize this dimension:

1. *mode*: synchronous and asynchronous;
2. *type*: direct in which a person communicates to one or more others or indirect in which a change is made to the shared representation;
3. *content* such as design process communication, participant attribution for contributions, design ideas and suggestions, design critique, and social communication;
4. *structure* of communications network, such as random or scale-free.

The *mode* of communication depends on whether the participants are present at the same time. Synchronous communication, requiring that participants be present at the same time, is supported by a chat window or by voice over IP. Asynchronous communication, where participants need not be aware of each other's presence and can contribute at different times, is supported by blogs, wikis, email, discussion forum, or documents.

The *type* of communication can be direct or indirect. Direct communication occurs when one participant sends or posts a message to one or more other participants with the intention of communicating about the problem. Indirect communication occurs when one participant makes a change to the shared representation that can then be seen by other participants. Heylighen [7] illustrates indirect communication with an example from nature: the construction of termite mounds, where the physical environment acts as the shared medium for collective knowledge. As each termite follows simple rules governing where to deposit mud (to place mud where the most mud is), the muddy towers provide a physical encoding of their collective efforts, a stigmertic signal available for all individuals to interpret. Wikipedia is an example of collective intelligence that occurs with both direct and indirect communication. Individuals can edit Wikipedia articles and thereby engage in indirect communication, and an individual can post a notice on the discussion forum and engage in direct communication.

The *content* of the communication is either a contribution to the shared representation of the problem, solution, or relevant domain knowledge, or is about the process. In collective design, communication about the process takes the form of design task or resource allocation, suggestions, critique, evaluation, and social communication. Design cognition studies using a protocol analysis have contributed to our understanding of the content of design communication by developing coding schemes that characterize this content. For example, Kim and Maher [9] develop a communication coding scheme, to compare collaborative design, using a keyboard and mouse, with collaborative design using tangible interaction technologies.

The *structure* of the communications network is an emergent property in collective design. Individuals are not equally connected to other individuals in a social network. Some people are highly connected with others, while some only possess a few connections. Although not all people will know each other in a large network, any two people can usually be connected by only a few links – links which usually pass through well-connected hubs. The structure of a social communications network is governed by the strength of the relationship between individuals. In a design team, the connections between individuals is usually evenly distributed as the team size is limited and the structure is formally defined, leading to a bell curve link distribution where most nodes have the same number of links, as shown in the left part of Fig 4.

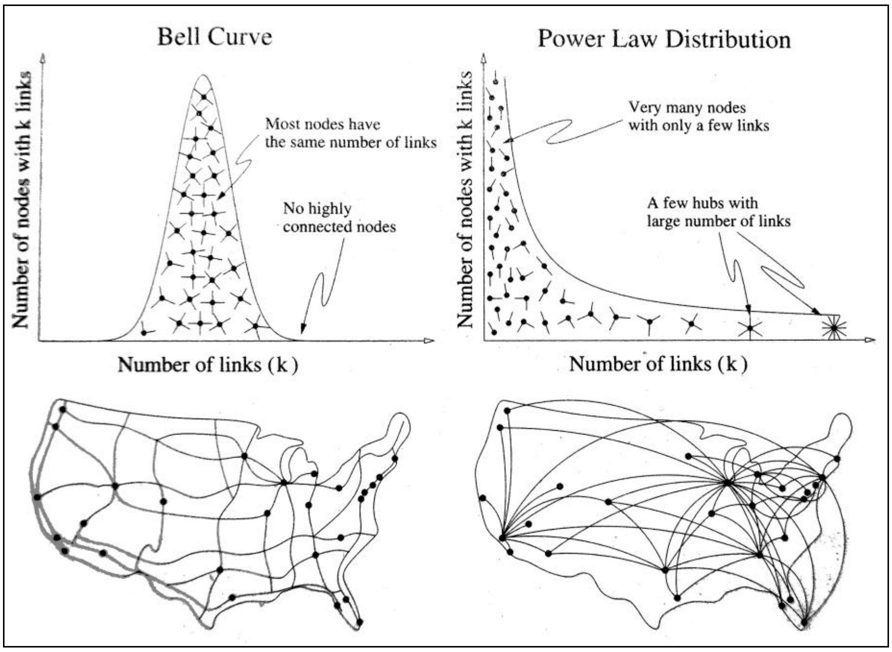

Fig. 4 Random and Scale-Free Networks from Barabasi [10].

Design communications occurring within an open community are not formally defined and links within them are more likely to form a power-law distribution, as shown in the right part of Fig 4.

2.3 The Motivation Dimension

For a conceptual space for collective design, we have developed the following categories of motivation. These have been drawn from categories of motivation identified in collective intelligence, open source software, and social psychology literature, briefly described after the list.

- *Ideology* – participation for the purpose of contributing to a larger cause.
- *Challenge* – participation that provides a sense of personal achievement through acquiring additional knowledge or skill.
- *Career*– participation that may lead to an advance in the individual's career.
- *Social* – desire to have a shared experience with one or more individuals.
- *Fun* – participation for the purpose of entertainment, enjoyment, excitement, relief from other experiences, or simply furnishing or structuring the passage of time.
- *Reward* – participation to receive tangible rewards includes money, points in a game, a gift or voucher.
- *Recognition* – participation in order to receive private or public acknowledgement.
- *Duty* – participation in response to a wish or command expressed personally.

A key dimension of the conceptual space that describes collective design is motivation: that is, the technologies and organizing principles that attract people to participate. Understanding the range of motivations is an essential dimension of collective design. It leads to guidelines for achieving participation from both designers, who may be involved because it is part of their job, and society at large, who may be volunteering their effort. Motivation theories have been developed from a range of perspectives: from Darwin's evolutionary theory contributing a biological basis for human motivation to intrinsic motivation as described in Maslow's hierarchy of needs which spans from the purely physiological to self-actualization. Merrick and Maher [11] provide an overview of motivation theories and their relevance to computational models of motivation as the basis for implementing a curious agent. Here we focus on studies of motivation as related to volunteer activities.

Malone et al [12] present an analysis of mechanisms that induce massindividual participation in several computer-enabled collective intelligence systems. In this study the range and instances of four parameters, or "building blocks" of a collective intelligence task, are framed as question pairs. *Who* is performing the task? *Why* are they doing it? *What* is being accomplished? *How* is it being done? Malone et al. identify three personal motivations, associated with the question, *Why are they doing it?* as money, love, and glory. The categories, money, love and glory, are useful generalizations, and are embedded in our categories: money is what we more generally refer to as reward, love is what we more generally refer to as social, and glory is what we more generally refer to as recognition.

Nov [13] identified 8 categories of motivation in a survey of people that contribute to Wikipedia, starting with 6 categories of motivation associated with volunteering defined by Clary [14]: values, understanding, enhancement, protective, career, and social. Nov's additional categories for understanding motivation in Wikipedia are fun and ideology, which are also used in research on motivation to contribute to open software development. Nov's survey found that the top motivations were fun and ideology. Our categories of motivation are more similar to Nov's categories, but also incorporates categories that describe the motivation of a selected design team and non-designers whose participation may be entirely informal and voluntary.

3. Mapping Collective Intelligence to the Conceptual Space for Collective Design

In order to better understand collective design, we review 6 successful examples of Internet applications that engender varying combinations of collected intelligence and collective intelligence and identify how they map onto our conceptual space for collective design. This process allows us to explore the conceptual space and develop principles for collective design.

Threadless[2] *- Crowdsourcing*

Threadless is a web site that encourages individuals to submit T-shirt designs. Every week the Threadless community votes for the best designs to go into production. The winning entrants receive a one-off monetary reward as well as a percentage of sales. Threadless has a thriving community actively engaged on a forum.

[2] www.threadless.com

- *Representation.* A textual description of the competition serves as representation. All current and archived T-shirt designs provide precedents.
- *Communication.* If the artist works independently, no communication occurs. Should the artist engage in the online community forum, collaboration on a design may occur, resulting in direct, asynchronous communication.
- *Motivation.* Primary motivators may include: the challenge of having their design selected for production; recognition arising from their username being associated with that design and promoted; the financial reward. Secondary motivations may include: the social aspect of communicating with like-minded people; fun – participating in something that may be a hobby or performed beside their primary source of income; career – the leverage their status provides to potential employers within the field (or a related field).

Google Image Labeler3 - Collected Intelligence

Google's Image Labeler presents a game-like scenario, to add tags to images, inviting users to work at categorizing online pictures in order to improve Google's search engine in exchange for points and gifts. Keywords from multiple sessions, of an image are compared and frequently occurring terms are allocated to the image permanently.

- *Representation*. The type of shared representation is the image and the content is the problem description. The shared representation for each problem is a simple structure and the contribution to the collected intelligence comprises one or more labels.
- *Communication*. The type of communication is indirect and therefore the mode is asynchronous. The content of the communication is a contribution to the solution, that is, the image label. The structure of the network is evenly distributed since the individuals do not communicate with each other directly.
- *Motivation*. The Google Image Labeler is structured as a game, where individuals are motivated to play in order to win and achieve recognition. Individuals are recognized when they become "today's top pairs" and when they become one of the top 5 "all-time contributors". The relevant categories of motivation are fun, recognition, and reward.

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[3] For more information see: images.google.com/imagelabeler

Wikipedia[4] – Hybrid Collected/Collective Intelligence
Wikipedia is often cited as an example of a kind of collective intelligence where many individuals work together to create a vast and socially constructed knowledge base. Any one individual contributes to only a few specific articles of interest, adding their knowledge to them. *Collective* intelligence is the phenomenon that lies behind the creation of each article, but Wikipedia itself, or rather the collection of articles that make up Wikipedia, is *collected* intelligence. This is why we place this example at the middle of the continuum, in Fig. 1.

- *Representation*. The type of shared representation comprises images, text, and links. The content of the shared representation is the "solution" or the shared knowledge on specific topics.
- *Communication*. Communication in Wikipedia is either direct, where participants can contribute to a discussion forum, or indirect, where participants can edit an article. The mode of communication is asynchronous so participants are not aware of the presence of others that may also be editing an article. The content of the communication is either the "solution" or knowledge in an article or comments about the changes to the article. The emergent structure of the social network of Wikipedia has been studied by many with varying conclusions.
- *Motivation*. The motivations of individuals that contribute to Wikipedia have also been studied by many. Based on Nov [13], the motivations that map onto our categories include: ideology, challenge, career, social, fun, recognition, and duty. The only motivation in our list that is not included is reward since there is no tangible reward for contributing to Wikipedia.

Kasparov vs The World[5] – Hybrid Collected/Collective Intelligence
A 1999 game played over the Internet by Gary Kasparov, the (now former) reigning world chess champion, against Team World, which comprised five consulting chess champions, chess clubs distributed internationally, any person with an internet connection wishing to participate, and strong chess analysis software. The combination of discussion over a forum and the played move being voted for by plurality, suggests both the collaborative aspect of *collective* intelligence and the wisdom-of-crowds-aggregation of *collected* intelligence. Through their combined effort, a novel move was played by Team World; one never made before in a recorded game.

- *Representation*. The type of the shared representation comprises image

[4] For more information see: en.wikipedia.org/wiki/Wikipedia:About
[5] For more information see [15].

and text and the content is the description of the problem and solution, that is, the chessboard, the rules of chess, and a decision tree.

- *Communication*. Both types of communication are supported: direct and indirect. The mode of communication is asynchronous. An MSN bulletin board was the platform on which online communication primarily took place. The content of communication included ideas and suggestions, critique and voting. The network structure was scale-free, with certain individuals communicating more frequently or influencing others more heavily.
- *Motivation*. Several categories of motivation apply to this example: fun, reward, recognition, challenge, career, social, and duty. Individuals were playing for points, to see if they could win against the world's master chess champion. Participants collaborated and were intellectually challenged. Participants became part of a global community and chess clubs also became involved.

I Love Bees[6] – Collective Intelligence

I Love Bees is a detective game that was played by over 600,000 participants, most of whom were avid fans of an earlier game, Halo, and were eager to learn more about the sequel to their game. Abstract clues were provided across a variety of media, including a "corrupted" web site. Users were not given any explicit instruction, although the game's designers intended the output to be a narrative providing the back-story to the Halo 2 game. Levels of collaboration were extremely high, with information amassed and elaborated on by many players as the narrative structure evolved.

- *Representation*. The type of shared external representation is text and the content is both the clues provided by the administrators as well as content created by the users. Ideas and theories about the mystery also became a shared representation. The problem was not given, but discovered by the players, as was the solution. The organizers provided constraints, in the form of raw data.
- *Communication*. Direct communication occurred over multiple channels, such as email, message board, phone etc. The I Love Bees project is a good example of how an ongoing conversation developed between players to enable a collective intelligence. The conversation emerged spontaneously from the use of existing tools they had readily available. Linking multiple platforms allows user interactions with data to be more fluid as information can be interrelated, manipulated and analyzed across a variety of tools and representations. Encouraging user

[6] For more information see [16].

deployment across a spectrum of situations/contexts enhances the accessibility and ubiquity of a system, and acts to maximize user involvement. Communication was direct and mostly asynchronous, although on occasion (such as during live chat) it was synchronous. Indirect communication took place by tweaking the original representations (raw data).
- *Motivation*. The participants were motivated by the challenge of the mystery, as well as for the social, fun, and recognition aspects of the activity.

TopCoder[7] *– Collective Intelligence - Crowdsourcing*
Top coder is inspired by the open source software movement adding a modern crowdsourcing approach. Coding projects are broken up into discrete elements, which are made available to anyone who wants to contribute. The submissions are checked for correctness and the community can then vote on the best code for each element. The best pieces of code are selected and the community is again challenged to synthesis the elements to a larger working program.
- *Representation*. A textual description of the code is provided. Inputs and outputs are identified.
- *Communication*. If the individual codes the task alone there is no communication. If collaboration is involved it could be indirect asynchronous (the code itself is modified by many) or direct asynchronous (ie. contributors discuss the coding over email) or direct synchronous (ie. they discuss the coding over chat).
- *Motivation*. Top Coder appears to invoke every motivation except duty. This is partly a legacy of the open source software movement's ideology of free software designed by the public, for the public, that was 'better' than the alternatives offered by industry. Individuals may contribute due to: the challenge of writing the code; the social aspect addressed by the community; or to enhance their career. Even though there is a financial reward if the code is selected, members don't participate simply because they *expect* to benefit financially.

4. Principles for Collective Design

The continuum for collective intelligence, shown in Fig 1, and the analysis of the examples described in section 3, are summarized in Table 1, below.

[7] http://www.topcoder.com/

TABLE 1: Analysis of Successful Examples of Collective Intelligence

	Google Image Labeller	Threadless	Wikipedia	Kasparov vs The World	I Love Bees	Top Coder
Representation						
type I = image(s) T= text 3D = 3D model DB = database	I	T	I+T	I+T	T	T
content P= problem description S= solution, knowledge, world model	P	P	S	P+S	P+S	P+S
Communication						
mode S= synchronous A= asynchronous	S	A	A	A	A+S	A+S
type D= direct I = indirect	I	D	D+I	D+I	D	I
Content C= comments E= entries V= votes B=broad range	0	C+V	C+E	C+V	B	B
structure 0= no structure S= scale free M= multiple E= emergent	0	S	S	E	M+E	S+E
Motivation						
Ideology	X		X		X	X
Challenge		X	X	X	X	X
Career		X	X	X	X	X
Social		X	X	X	X	X
Fun	X	X	X	X	X	X
Reward		X		X	X	X
Recognition		X	X	X	X	X
Duty			X	X	X	

The table provides a basis for developing principles for collective design by considering the extremes in the continuum: collected design intelligence to collective design intelligence. Collected design intelligence, that follows from successful examples of collected intelligence, should be structured around encouraging and enabling large scale participation in design tasks, such as identifying novel and useful features of design alternatives, and identifying labels for new design ideas. Collective design intelligence should be structured around encouraging and enabling large-scale participation in design tasks, such as brainstorming, concept analysis, ideation and competitive design solutions. Key questions and answers are:

What is the function of the shared representation? A shared representation has multiple vital roles. The type and content provide the basis for defining what participants can do and for motivating people to participate. A collected intelligence task like the Image Labeler has a very simple shared representation and a collective intelligence task has multiple types of representation and requires skill to navigate and manipulate the shared representation. A principle for collected intelligence in design is to keep the shared representation simple and modular. A principle for collective intelligence in design is to develop an adaptive and dynamic shared representation that allows the individuals to express themselves through the shared representation.

How do people communicate? The successful examples of collective intelligence do not provide a recipe for an ideal type and mode of communication. The I Love Bees example shows that people will create their own way of communicating if they are highly motivated to participate. However, in collective design, facilitating communication across a range of types and modes will make it easier for participants to join and interact. There are many studies and lessons learned from computer supported collaborative work and social networks for principles of effective communication. In addition to computer supported communication, there are examples of machine learning systems that can aggregate and find patterns in communication data and human activity, such as recommender systems, that will enhance indirect communication in collective design.

Why do people participate? While some of the participants in collective design will be motivated by duty and career, the non-specialist designers need to be motivated by the categories typically associated with volunteer activities. These categories include fun, challenge, ideology, social, reward, and recognition. In developing collective design, a mapping from these categories of motivation to organizing principles in the way the design tasks are presented and structured is essential. The most popular motivation for Wikipedians is fun, suggesting that a game-like environment is a good starting point. A game-like environment addresses the motivation categories; fun, social, reward, and challenge. A design task that promises to make the world a better place addresses the motivation categories; ideology and recognition.

In summary, this paper presents a conceptual space for collective design that leads to design environments that encourage large scale participation in the next generation of challenging design tasks. Developing successful collective design starts by understanding how individual and collaborative design is supported with computing technology and then going beyond collaborative design to structure and organize the design tasks so that people are motivated to participate. The analysis in this paper develops and illustrates several categories of motivation to be considered when implementing an environment for collective design.

5. Conclusions

Collective design is a phenomenon that can occur when large numbers of motivated professional and amateur designers contribute to a collective intelligence that emerges from their mutual communication, collaboration, and competition. This paper proposes that design outcomes from collective processes can be greater than can be achieved by a preselected team of designers, participating in a collaborative process. The successful examples in design domains "crowdsource" individual designs from very large crowds where the individual benefits from participation in a community. Beyond this, collective design can draw on contributions from large numbers of human and computer agents to complex design problems. Collective design is possible because the internet facilitates participation from individuals who are not preselected, but are motivated to participate for personal reasons that go beyond financial reward. This paper articulates several kinds of motivation in successful collective intelligence as part of a framework for understanding collective design and serves as a basis for designing systems that enable large-scale collective design.

References

1. McDonough W and Braungart M: 2002, *Cradle to Cradle*, North Point Press.
2. Nakakoji, K, Yamamoto, Y and Ohira, M: 1999, A Framework that Supports Collective Creativity in Design using Visual Images, in *Creativity and Cognition 1999*, ACM Press, New York, NY, pp. 166-173.
3. Farooq, U, Carroll, JM, Ganoe, CH: 2005, Supporting creativity in distributed

scientific communities, *ACM SIGGROUP conference on Supporting Group Work*, pp 217 – 226.
4. Howe, J: 2009, *Crowdsourcing: Why the Power of the Crowd is Driving the Future of Business*, Three Rivers Press, pp336.
5. Halpin, H: 2008, Foundations of a philosophy of collective intelligence, in Guerin and Vasconcelos (eds) *AISB 2008 Convention: Communication, Interaction and Social Intelligence*, University of Aberdeen, UK pp12-19.
6. Gruber, T: 2008, Collective knowledge systems: Where the social web meets the semantic web, *Web Semantics: Science, Services and Agents on the World Wide Web* 6: 4-13.
7. Gul, LF and Maher, ML: 2009, Co-Creating external design representations: comparing face-to-face sketching to designing in virtual environments, *CoDesign International Journal of CoCreation in Design and the Arts*, **5**(2): 117-138.
8. Maher, M and H Tang: 2003, Co-*evolution* as a computational and cognitive model of design. *Research in Engineering Design*, 14: 47-63.
9. Levy, P: 1997, *Collective Intelligence: Mankind's Emerging World in Cyberspace*, Plenum, New York. Translated from the French by R. Bononno.
10. Heylighen, F: 1999, Collective intelligence and its implementation on the web: Algorithms to develop a collective mental map, *Computational & Mathematical Organization Theory* **5**(3): 253-280.
11. Keel, PE: 2007, EWall: A visual analytics environment for collaborative sense-making, *Information Visualization* **6**(1): 48-63.
12. Kim, MJ and Maher, ML: 2008, The Impact of Tangible User Interfaces on Spatial Cognition During Collaborative Design, *Design Studies* **29**(3): 222-253.
13. Barabási, A-L: 2003, *Linked: How Everything is Connected to Everything else and what it means for Business, Science and Everyday Life*, Plume, NY pp71.
14. Merrick, KE and Maher, ML: 2009, *Motivated Reinforcement Learning: Curious Characters for Multiuser Games*, Springer-Verlag Berlin Heidelberg pp206.
15. Malone, TW, Laubacher, R and Dellarocas, C: 2009, Harnessing crowds: Mapping the genome of collective intelligence, MIT Sloan School Working Paper 4732-09, available online: http://ssrn.com/abstract=1381502, accessed 07/01/10.
16. Nov, O: 2007, What Motivates Wikipedians? *Communications of the ACM* **50**(11): 60-64.
17. Clary, E, Snyder, M, Ridge, R, Copeland, J, Stukas, A, Haugen, J, and Miene, P: 1998, Understanding and assessing the motivations of volunteers: A functional approach. *J. Personality and Social Psychology* **74**: 1516–1530.
18. MSN: 1999, World Chess Champion Garry Kasparov Defeats World Team in Kasperov vs The World on MSN.com Available online: http://www.microsoft.com/presspass/press/1999/oct99/kasparovwinspr.mspx
19. McGonigal, J: 2008, Why I love bees: A case style in collective intelligence gaming, in K Salen (ed) *The Ecology of Games: Connecting Youth, Games, and Learning*, Cambridge, MA pp. 199-228