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Formal Design Concept And Participant Behavior Analysis For Crowdsourcing Design

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DEDICATION

"To my beloved ones…."

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CHAPTER 1.

INTRODUCTION

1.1. Background

In product development, the advancement of technology always brings new product development trends, such as Ford's conveyor belt system. The current technology advancement goes faster and faster than ever. This quicker change in technology requires a quicker response for shifting paradigm of product development. In recent years, social media and technology have emerged and prevailed in our lives and have lead the related industry to the new product development era. The social-driven opportunities change most of the paradigms in industries and product development area once again. This trend is affecting the whole spectrum of processes in the product development with changing roles of traditional stakeholders. The customers who played a role as buyers in traditional product development are now contributing as active actor or participants to develop new products with their own ideas, concepts, designs, or even ready-to-make prototypes [Bertoni et al., 2012a; Bertoni et al., 2012b]. Also, the impact of social media in the product development and product innovation process leads the customers as the member of co-creation of the products [Piller et al., 2010; Piller et al., 2011]. Examples of crowdsourcing types are shown in Figure 1.1.

1.1.1. New Product Development in Crowdsourcing

After the concept of crowdsourcing was coined by Howe [Howe, 2006], new crowdsourcing services are introduced in the New Product Development (NPD) field with the rising of open R&D and innovation [Enkel et al., 2009]. Current research efforts show that crowdsourcing has become the most popular form of encouraging customer participation in the

design of new products [Terwiesch and Xu, 2008]. Huang and her colleagues classify the three types of crowdsourcing for new product design ideas depending on customer participation types [Huang et al., 2011]. The first type is that the customer participation covers the creation of a roughly specified product and depends fully on customer input. An example of the first type is Threadless.com which collects the finished t-shirt designs from customers. The second type of crowdsourcing is related to the first type. The similar point is that the final design depends fully on the customer submission but the difference is that a specifically defined task or problem has to be solved by customers [Jeppesen and Lakhani, 2010]. Quirky.com corresponds to this type. Quirky.com gathers product ideas, design, development, and data science to commercialize the initial idea as a real product. In other words, the idea generators or designers are not necessary to be problem solvers. The third type of crowdsourcing is related to a permanent open call for contribution. This type of crowdsourcing is not related to any specific task or problem [Bayus, 2010; Gangi et al., 2010]. Dell Ideastorm is an example of this type. In this type of crowdsourcing, customers contribute and evaluate various ideas. The decision to develop and implement those ideas depends on the firm. Other examples of crowdsourcing platforms are shown in Figure 1.1. In the next section, we will discuss the relationship between concept development (or concept management) and crowdsourcing design.

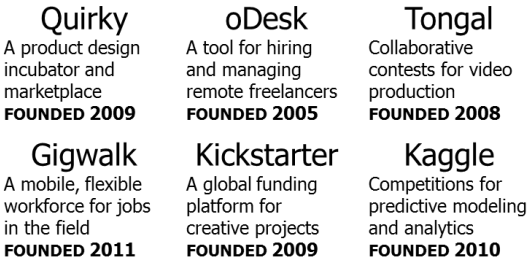

Figure 1.1 Examples of crowdsourcing platforms

1.1.2. Activities for Product Concept in Crowdsourcing

As aforementioned in the previous section, the main activities for concept development and management are related to the 'design' of new products. Project initiators propose the new product concepts and other team members develop those concepts with designers and engineers who are assigned as the product development team. In a crowdsourcing environment, on the other hand, idea generators and designers as initiators are not involved in a firm. They provide their own ideas and designs to crowdsourcing services as a new product concept and the rest of the participants work as respondents by contributing their votes, comments, or alternative designs. The critical difference related to concept management between current design environment and crowdsourcing environment is the origin of the resource. Although outsourcing concept exists, crowdsourcing is different from outsourcing. The new features of crowdsourcing design concept management are extracted from these differences. Geiger and his colleagues propose the four dimensions of crowdsourcing [Geiger et al., 2011]. The first dimension, pre-selection of contributors, is concerned with restrictions regarding the pool of potential participants. The second dimension, the accessibility of peer contributions, indicates to what extent participants can see each other participant's contributions. Aggregation of contributions is the third dimension and describes how the crowd contributions within a crowdsourcing NPD are applied by the crowdsourcing service to achieve the desired outcome. The fourth dimension, remuneration for contributions, determines how contributors are rewarded for their work. These four dimensions are relevant to the concept management. 'Pre-selection of contributors' in crowdsourcing is the process of finding participants who will conduct the given project. This is similar to creating a project team for concept selection and concept testing in a general firm. 'Accessibility of peer contributions' is the possibility of collecting information that is used for

identifying and analyzing the expertise of participants in the process of finding participants. Also 'remuneration for contribution' is the process to evaluate the participant's ability and expertise based on the object assessment measures such as total earning in Quirky.com. As noticed, the management of idea and design source such as respondents or participants is the most important factor to success in the crowdsourcing design.

1.1.3. Difficulties for Design Evaluation in Crowdsourcing Environment

In order to conduct a new product development project in the current firms, it is important to determine who designs a concept for a new product. However, it is difficult to figure out the designer in the crowdsourcing environment where the anonymities of participants are guaranteed. Only information to distinguish and identify a specific participant is based on the information that is given by participant him- or herself. Based on the information given by a participant, it is hard to fully trust the expertise of the participant. In a crowdsourcing environment, it is also difficult to find designers who fit on a specific crowdsourcing NPD project. It is not guaranteed that a designer who can provide proper ideas or contributions for a crowdsourcing NPD. In order to resolve this difficulty, functions or services to find proper participants such as idea generator and designer who meet criteria should be provided. After finding such participants, it is important to check their availability to contribute to the project. The availability is mainly related to a time issue. Waiting time to participate in a project and due date for a project can be examples of availability. Measures should be provided to overcome such difficulties in a crowdsourcing environment for implementing functions to find proper participants.

1.2. Research Questions and Objectives

The contribution of this research is in many folds. A major contribution of this research focuses on conducting analyses for understanding formal design concepts and participants' behavior that occur in the crowdsourcing design environment to fulfill the following research questions: (1) how crowdsourcing design activities of participants are captured as design information to develop a product in a crowdsourcing platform in the perspectives of process and elements, and (2) how a method extracts and represents the explicit or implicit hidden design concepts from crowdsourcing design activities systematically. To answer the research questions, the objectives and the importance of this research are outlined as follows:

(a) *Development of taxonomy to represent crowdsourcing design activities*: Crowdsourcing design processes or environment has unique characteristics compared to conventional design processes such as anonymity of participating designers, sparse information, and so on. In order to set a basis for analyzing crowdsourcing design, it is critical to build a taxonomy of potential design features. In order to include participants' information as well as physical product design features in this environment, a comprehensive taxonomy is required. This is the first objective of this research.

(b) *Extraction and representation of design concepts from crowdsourcing design activities*: The main objective of this research is to identify and analyze formal design concepts developed by crowds. For this purpose, design concepts should be extracted from the activities of participants and has to be expressed in formal representative methods. By applying the results of the first objective of figuring out what design features are applicable in crowdsourcing design.

(c) *Adoption of a theory from social science to engineering to explain the participants' design activities and behaviors as socialization in crowdsourcing design*: Many researchers, especially in Socio-Technological Study (STS), have attempted to apply social science approaches in order to enhance the level of understanding of the phenomena in engineering design fields; however, there are few methods that systematically represent design activities or knowledge with formal representation methodologies. Since crowdsourcing design activities are performed in a social network or social media platform, it has to 'resemble the social' activities for creating and improving a design. Thus, the third objective of this research is to adopt a theory from social science to engineering to explain the participants' design activities and behaviors as socialization in crowdsourcing design.

1.3. Scope of Research and Limitations

In detailing the scope and limitation of this research, three considerable folds are presented below.

The first issue is related to the definition of 'concept'. In this research, the term of 'concept' is used three fold: (1) concept in 'design concept', (2) concept in 'formal concept analysis', and (3) concept generated or extracted from crowdsourcing design activities. For the purpose of this research, 'concept' is defined as 'the collected pieces of data or information in regards to participants and design features to describe a product design or to be used for improving a proposed product idea', especially in chapter 4.

Secondly, among various types of crowdsourcing, this research solely focuses on the type of new product development by the design crowds. As illustrated in section 1.1.1, various types

of crowdsourcing are available now. However, the collaborative work to develop or improve a product in an open innovative environment is limited to NPD type crowdsourcing. On the contrary, type of contest, type of assigning a problem to a specific user, and any type of crowdsourcing without participant collaboration are not considered in this research.

Thirdly, a limitation comes from the constraints when apply social science theory directly into an engineering domain. Usually, social (technical) science research efforts are not quantitatively measured to validate the results of research. In this research, therefore, qualitative validation is conducted as a case study.

1.4. Dissertation Layout

The remainder of this research is structured as follows:

Chapter 2 summarizes the literature review related to crowdsourcing design, conceptual design, and Actor Network Theory (ANT).

Chapter 3 presents a formalism of 'translation' in ANT in order to apply crowdsourcing design and validate the processes of translation by comparing the processes of original reference and actual case with a real example.

Chapter 4 develops a formalism to extract and represent design concepts in crowdsourcing design by applying Galois lattice concept analysis method.

Chapter 5 concludes the research by highlighting the contributions of this research to further crowdsourcing design and discussing future works for the further improvement.

CHAPTER 2.

RESEARCH BACKGROUND AND LITERATURE REVIEW

2.1. Crowdsourcing

The terminology with regarding to crowdsourcing is not clearly defined in the extant academic literature. First, the concept of crowdsourcing is firmly settled down to other similar concepts such as open innovation, mass collaboration, crowdcasting, and wikinomics [Schenk and Guittard, 2010; Marjanovic et al., 2012]. Existing academic literature refers various terms to describe related services or activities, such as peer production, collaborative systems, collective intelligence, crowd wisdom and mass collaboration [Doan et al., 2011]. Other terms often referred in the literature include consumer co-creation [Hoyer et al., 2010], open innovation [Chesbrough, 2003], user innovation [von Hippel, 2005], collaborative innovation [Sawhney et al., 2005], customer empowerment [Fuchs and Schreier, 2011] and used-generated content [Liu et al., 2011].

2.1.1. Typology

Crowdsourcing originated from open source software development where a community of programmers voluntarily contributed their time to creating and building novel products such as the Linux operating system or the Firefox web browser [Howe, 2008]. Typically articles on crowdsourcing refer that the term itself was coined by Jeff Howe. In Wired magazine, he popularized 'crowdsourcing' and defined it as *"crowdsourcing is simply the practice of companies making an open call to a broad community to solve a problem, either through competition or collaboration"* [2006]. Detailed discussions about the terminology and definitions of crowdsourcing are conducted by Brabham [2008], Schenk and Guittard [2010],

and Whitla [2009]. Recently, Estellés Arolas and González-Ladrón-de-Guevara [2012] created a global definition to describe any given crowdsourcing activity by analyzing more than 200 related documents and extract 40 original definitions for the term 'crowdsourcing'. They consequently integrated and consolidated common elements from these various definitions in order to create a single, consistent and all-inclusive definition.

Even though extant effort to identify and define the concept of crowdsourcing by researchers, a commonly accepted taxonomy of crowdsourcing does not exist. The efforts to build a common taxonomy for crowdsourcing are conducted. Four key components consist of a process of crowdsourcing: pre-selection of contributors, accessibility of peer contributions, collection of contributions, and rewards or compensation for contributors [Doan et al., 2011; Geiger et al., 2011]. Malone et al. also identified the core organizational genes: the goal, participant, process, and incentive [2009]. Crowdsourcing tasks can be simple, complex or creative in nature. Simple tasks are typically micro-tasks, such as short translations, interpretations of visual data as text, or casting a vote [Schenk and Guittard, 2010].

Activities for crowdsourcing usually conducted at a web-based environment. A crowdsourcing system is that "enlists a crowd of humans to help solve a problem defined by the system owner" [Doan et al., 2011: 87]. Crowdsourcing is being used by increasingly by the public and governmental sector as well as by private firms [Marjanovic et al., 2012]. A considerable proliferation in the amount of different platforms or systems is there. Hossain et al. [2012] identified and analyzed more than 400 crowdsourcing platforms and services to emerge. The most famous and cited crowdsourcing examples are Threadless, Lego, and Quirky.com [Brabham, 2008]. Threadless is a new business model that users contribute in designing and

voting for T-shirt designs. Lego connects hobbyists or Lego lovers by creating new designs for toys, and Quirky allows people to upload a new product idea and build with collaborators [Howe, 2008; Li and Bernoff, 2008; Brabham, 2012]. There are also new initiatives and platforms called 'crowdfunding' which is aimed at advertising projects for fund-raising, such as Indiegogo and Kickstarter. For market research and promotional purposes, crowdsourcing is also possible to be used [Whitla, 2009]. Various question-and-answer sites, such as Quora.com, or micro tasking sites, such as Amazon Mechanical Turk can be other examples of crowdsourcing initiatives.

2.1.2. Idea generation and problem solving

The main purpose and the potential of crowdsourcing are related to creating or generating new ideas and innovations, effective problem solving, reducing costs and quickening the product development with fully or semi-anonymous contributors [Brabham, 2008; Vukovic, 2009]. Instead of depending on the brainpower of a few experts, crowdsourcing collects ideas from a large group of participants [Surowiecki, 2004]. An idea contest is already prevailing as a method of collecting ideas from the crowd. An example from the 15th century where authorities in Florence invited for everyone to design what would be the world's widest and tallest dome for their city's new cathedral [Boudreau et al., 2011]. Another historical example is related to 'longitudinal systems': the British Navy gave an open call for external expert groups to solve the problem related to longitudinal navigation that created troubles to the navy for a while [Spencer, 2012]. In both cases, the solutions originated from a unexpected source rather than from well-known experts or expert groups. In this sense, one of the main differences between traditional outsourcing and crowdsourcing is that the person who will be compensated does not depend on the known a priori [Marjanovic et al., 2012].

Currently many firms organize the idea contests by themselves [Ebner et al., 2009] or use an external idea contest platform service provider. Piller and Walcher discussed the process and mechanism for organizing idea contests [2006]. Even though the profits of idea contests, Boudreau et al. addressed that the level of uncertainty should be assessed carefully before an idea contest is launched [2011]. Lopez-Vega and Vanhaverbeke proposed to use innovation intermediaries as traders for another alternative [2009]. The value of innovation traders depends on having established networks of problem solvers and connections with companies seeking for solutions for their problems [Lopez-Vega and Vanhaverbeke, 2009]. Innocentive is a well-known and one of the biggest intermediaries. It has enlarged an online network of more than 200,000 people to provide solutions for major problems such as the Exxon oil spill in Alaska [Chesbrough, 2011].

The motivations that actual users are willing to participate in idea contests are very diverse. One critical factor is that the benefits or rewards need to outweigh the cost of time and effort from the participant's perspective [Vukovic et al., 2010].

2.1.3. Advantage of Crowdsourcing

Many researchers address that the advantage of crowdsourcing comes from the knowledge and experiences of contributors that were previously unknown and unavailable [Bogers and West 2012; Malone et al. 2009]. As the pattern of participation, contributors work in a divide-and-conquer format, supporting a wide and quick exploration of problems with various perspectives and content [Erickson, 2011; Geiger et al. 2012]. On the other hand, the challenges also come from the variety of contributors. Effective incentives, proper tasks, management of multiple submissions for varying quality, and arranging unpredictable actions should be offered

by crowdsourcing initiators or platform providers [Malone et al., 2009; Jain, 2010]. Since varied contributors usually participated at different times in crowdsourcing, the synchronization with collaborators can be another challenge. This collaborative process in crowdsourcing might reduce the quality of collaborative works.

2.2. Crowdsourcing Design

2.2.1. Crowdsourcing Design

Design is supported by crowdsourcing. The vast knowledge generated and contributed by crowds enhances a wide exploration of design ideas. Companies created communities and groups to get reviews or feedback and creative ideas for developing their products [Bayus, 2013]; those companies also broadcast their own design tasks and select solutions from crowd's participations. As idea contest, design contest is also the main type of crowdsourcing design. 99designs hold manifold design contests, broadcast the contests to contributors to submit ideas, and reward the best. As well as the best idea, other submitted ones contribute to contest initiators with novel insights and commitment toward the main design problem [Tidball et al. 2011; Sun et al., 2014].

Many research efforts are conducted to apply various methods for supporting crowdsourcing design. Wooten and Ulrich addressed that the direct feedback to contributors improves the quality and amount of submissions [2011]. Supporting work group, aligning incentive to desired behavior, and monitoring the use of other sources fostered creativity are recommended as supporting methods for crowdsourcing design [Dontcheva et al., 2011].

Collaborative group crowdsourcing design is another direction of research to enhance crowdsourcing design. Although aforementioned methods improved the quality of ideas, those still didn't change the way of idea generation. Contributors still work individually to create,

improve, and develop their ideas. Since that, this individual work has two disadvantages: limited consideration of alternatives which leads to relatively low chances of reward and lack of tracing the crowd's design rationale.

Studies on group design contribute to crowdsourcing design with valuable references. Linsey et al. [2011] addressed that the ideas proposed by a design group member triggered others' connected design concepts which were difficult to retrieve and lead to result in better one. With the efforts to address the advantages of group design, methods to enhance group design were developed. For example, C-sketch passes and share design sketches with the design group so that designers are able to modify others' ideas [Shah et al. 2001]. Filter Mediated Design is another example. It filters the modified part of design ideas and consolidates them in a unified way for further modification [Haymaker et al. 2000]. These methods help to improve the quality of ideas.

A collaborative crowdsourcing design method divides the design process into basic steps [Nickerson and Sakamoto, 2010; Yu et al., 2011]. Ideas are submitted first, and better ideas are chosen to stimulate them and delivered to another design group, inducing next-generation ideas. This type of collaboration consists of individual crowdsourcing processes. Even when the next-generation ideas are simply combined the prior ideas, their quality scores of the ideas still increase.

2.2.2. Participatory design

Participatory design is mistakenly considered as a type of crowdsourcing design. Unlike crowdsourcing design, participatory design is related to both the process of design and research. Although the difference between crowdsourcing design and participatory design, they have a common interest as the philosophy of collaboration. The origin of participatory design is

different from current technology-based collaborative design. The outcomes of design can be objects, systems, services, and the like, while the outcome of research is information and knowledge [Spinuzzi, 2005]. Until all participants agree with the outcomes, participants can interpret the generated design considering by envisioning, shaping and transcending the design activities. All participants have same privilege in a network aligned with a mutual interest to create and develop new designs. The input and involvement of community stakeholders are essential for successful research [Mosavel et al., 2005]. Therefore, the participation process started with forming a trust relationship among participants.

Byrne and Sahay's [2007] findings for the PD indicate that it is necessary to go beyond end user participation to also consider the persons affected through the delivery. They also address that a multi-level and multi-sectorial approach should be adopted. Community participation in developing contexts is more complex than has been reported in the literature [Bailur, 2007]. Even though these findings addressed the system level considerations, this approach also required to be applied when crowdsourcing design services are developed.

The level of participation is not always the same during all the phases of a product development. It may include all the users or representatives of users. Also the content may include technical, social aspects or both [Maail, 2011]. In addition, Maail [2011] also suggests that user participation has to correspond to the conditional factors of the context regarded as the optimal level of participation rather than a high degree of participation.

In participatory design, the following challenges are emerged by mobile development. First, user interfaces should be developed with accessibility of differently-abled users. Second, the complexity of developing applications across multiple mobile platforms should be considered

and handled. Last, the functionality of treating the uncertainty of specifying requirements [Dehlinger and Dixon, 2011].

2.2.3. Community-based Design

As a comparison of crowdsourcing, community-based design is usually mentioned in design field. In this section, it is discussed what community-based design is and what the differences between crowdsourcing and community-based design are briefly.

The concept of community-based design was introduced in the late 1960s as an alternative to traditional practice of planning and architecture [Rios, 2006]. This community-based approach to design is taught in many schools and practiced by numerous organizations and individuals in the public and private sectors alike. Recently, however, there has been great development in the Web technologies and open-source tools that allow participants easier access to technically challenging tasks such as electronics, software programming, and even product design. Projects such as Arduino and openFrameworks aim to provide participants with usable and accessible tools for creating new designs. This ease of use is "built on strong on-line communities full of relevant information" [Hutter et al., 2011]. For example, Arduino provides detailed information about devices, including project examples, technical documents and links to related external web content as well as a forum where participants can share ideas, help one another and discuss their projects. The main difference between crowdsourcing and community-based design are 'expertise' and 'anonymity'. Based on Hutter et al.'s address, participants in community-based design contribute to collaboration with full of relevant information on strong on-line communities. This means that participants in community-based design are preferred to have strong knowledge about projects or designs and also they already have relationships each

other. On the other hand, participants in crowdsourcing design are not required to have strong knowledge about projects or design. They do not have strong relationship each other usually and are not required. These differences require building a methodology to identify the relationships between participants in crowdsourcing design.

2.2.4. Collaborative Conceptual Design and Its Systems

Collaborative design is defined as the design process when a product is designed and developed through the activities of many designers who provide the effort collectively and jointly with one another [Wang et al., 2002]. It is also called co-operative design, concurrent design, or interdisciplinary design. Collaborative design consists of multiple functions such as designing, manufacturing, building, testing, and purchasing as well as those from external stakeholders, suppliers, and even customers.

Conventional design systems have followed a sequential model to generate designs. It divides the design task into sub-tasks that are sequentially conducted in a pre-defined pattern. However, this design pattern has been changed. Many research works argue the problems of sequential design. First, it is easily breakable and inflexible. Second, sequential design often requires numerous iterations to cause the design expensive and time-consuming. Last, sequential design also limits the possibilities of design alternatives. Collaborative design tries to overcome these problems contemporarily. Emerging technologies including the Internet and Web technologies have been applied to implementation and development of collaborative design systems.

For last two decades, the Internet and Web technologies had rapidly emerged in the market and also applied to design supporting tools for collaboration. Wang et al. [2002] propose

the primary functions of Web-based collaborative design tools: (1) access to catalogue and design information on components and sub-assemblies, (2) authenticated access to design tools, services and documents, and (3) communication among multidisciplinary design team members in multimedia formats.

Collaborative design tools have been enhanced by various information, graphic, and visualizing technologies. Extant collaborative design tools are supporting the collaborating works among designers. Even though current collaborative design tools have also been developed appropriately, they are also limited functionality to support the crowdsourcing design environment. It is focused on the domain-specific engineering design problems and the associated optimization and selection issues. Since non-expert as well as professional designers can involve in the process of crowdsourcing design, an approach to extract information from design activities and support their participations is required. This research presents a method to extract those participants' efforts with systematic and formularized approach for crowdsourcing design.

2.3. Participant Behavior in Social Media

In order to investigate participant behavior in social media, it is necessary to confirm with two aspects: (1) usage motivation as individuals and (2) network characteristics of social media as social behavior. In this section, the factors of usage motivations of individuals are confirmed by individual usage motivation and the social characteristics of social media are confirmed by 'influentials' and network characteristics.

2.3.1. Usage motivation of social media

Social presence

'Social presence' means that the degree of perception to consider communication media as face-to-face communication socio-emotionally [Short et al., 1976]. In other words, it is the degree of feeling how much individuals are related to other users in the process of mutual communication. Social presence plays a role that increase the communication power of information in Web as forming sociable feeling between users by arousing non-face-to-face structure in on-line spaces. In case of forming the level of social presence high between participants during conducting complex, new, or ambiguous tasks, it tends to achieve highly in those tasks.

Pleasure or Enjoyment

The concept of pleasure is difficult to define clearly, but usually interpreted in the perspective of motivation. Also some researchers explain pleasure as the same concept of 'play' [Lin et al., 2005]. Pleasure is considered as the psychological status or characteristic of individual user or as internal usage motivation. Internal motivation defines as the motivation of achieving participation itself, while external motivation defines as the motivation which can occur by the belief that behavior can be a tool to bring valuable results [Hachbarth et al., 2003].

Usefulness

Davis et al. [1989] proposed TAM [Technology Acceptance Model] based on TRA [Theory of Reasoned Action]. In TRA, he proposed two variables which influence technology acceptance, usefulness and ease of use. Usefulness defines "the extent to which a person believes that using the system will enhance his or her job performance". Venkatesh & Davis[2000] addressed that social influence and perceived tools can be significant variables to [perceived] usefulness.

2.3.2. Characteristics of Network with Social Influentials

Generally, ‘influence’ is to change perception, attitude, and behavior of people [Raven, 1965]. It is one of the critical research topics with regard to the influence of diffusion of new information technology to communication that the research efforts investigate the characteristics of ‘influentials’. Watts and Dodds [2007] addressed that influentials play a critical role as opinion leaders or trend setters and are evaluated as “special individuals who influence directly the speed of adopting new technology”.

Lazarsfeld et al. [1948] proposed ‘two-step flow theory’ of communication which was the first systematic research work about ‘opinion leader’. They argued that information or influence is delivered directly to acceptors by opinion leaders who express their opinion aggressively rather than by mass media. After the work of Lazarsfeld et al., many researchers kept investigating the characteristics of those ‘special individuals’ who influence public opinions, believes, or consuming behaviors of consumers or users: ‘influentials’[Merton, 1968; Weimann, 1994; Keller & Berry, 2003], ‘influencer’ [Rand, 2004], ‘e-fluentials’[Recupero, 2001], ‘Hubs’[Rosen, 2000], ‘mavens’[Feick & Price, 1987; Gladwell, 2000]. Although the keywords and behavioral features are different based on media environment, they have researched ‘influentials’ that the ‘influentials’ influence the process of communication and information diffusion in the essential perspective.

However, emerging of the Internet and social network environment challenges the phenomenon that the diffusion of information is led by limited influentials, so called ‘Influentials Thesis’. By simulation, Watts and Dodds [2007] addressed the role of ‘ordinary people’ as well as influentials. In other words, it is true that a few influentials affect the diffusion of information,

but the diffusion of information cannot be interpreted properly without the collaborative contribution of ordinary people. This criticism has provided the turning point to further social network theories by addressing the importance of the network effect than a few influentials. It also addressed the needs of scientific analyses that investigate the mechanisms of influence which is diffused by huge networks.

As mentioned above, 'influentials' and 'ordinary people' are coexisting in actual social media. Therefore, a theory which can explain these two perspectives is needed. Actor Network Theory as a theory which can be applied to this complex phenomenon is introduced in the next section.

2.4. Actor Network Theory

Michel Callon, Bruno Latour and John Law worked to propose the Actor Network Theory [ANT] [Callon, 1986; Latour, 1987; Latour, 2005; Law, 1987; Law, 1992; Law and Hassard, 1999]. ANT explains how material-concept networks come together to act as a whole. Before directly adopting ANT to crowdsourcing, it is necessary to discover the characteristics of ANT, which allow it to be the solution of existing research problems in crowdsourcing area [Callon, 1986; Latour, 1987; Latour, 2005; Law, 1987; Law, 1992; Law and Hassard, 1999].

ANT has four characteristics to describe society. First, ANT is used for describing heterogeneous networks, which are complex, fluctuated, and intertwined. The second characteristic is that ANT assigns active roles to non-human actors. The human society is a complex of human and non-human actors. It is difficult to imagine a pure society except non-human actors as well as it is also difficult to imagine a society without human actors. In ANT, the non-human is an actor as well as a human. Third, the actor in ANT is the network itself. By

Latour's explanation of ANT, the current 'I' is the same as a heterogeneous network connected between other human and non-human actors [Latour, 1987]. In this matter, non-human actors are also heterogeneous networks as well as 'I' am. The action power of 'I' means the relational effect generated by the other actors who are connected with 'I'. The last characteristic is that the process of constructing network is 'Translation' and the core of ANT is to understand 'Translation' [Callon, 1986]. Translation is the process of constructing ANT. The core of translation is an action to create a framework to replace one actor's understanding and intention with other actors' language. The process of translation is one of creating the orders. If this process is achieved successfully, a few actors who conduct this action can have the right to represent other actors' understanding and intention in the network. Translation process is explained in detail at the following section.

2.4.1. Translation in Actor Network Theory

Translation involves associating "heterogeneous entities" to form an actor-world through assigning, to each, "an identity, interests, a role to play, a course of action to follow, and projects to carry out" [Callon, 1986]. In this way, the translator becomes the "spokes [person] of the entities he [or she] constitutes," expressing or interpreting "their desires, their secret thoughts, their interests, their mechanisms of operation" [Callon, 1986]. Meanwhile, "roles are not fixed and pre-established" [Callon, Law and Rip, 1986], and different actors may combine and define these entities in completely different ways to "construct a plurality of different and incommensurate worlds" [Callon 1986], none of which can be shown to be any more "real" than the others. Having "spoken for" the other entities in the scenario it has delineated, the translator next attempts to make itself an "obligatory passageway", "a strategic point through which the

actor world must pass" [Callon 1986]. In other words, the translator defines what the other actors desire to obtain, and then attempts to demonstrate that the only way to achieve these goals is with the translator's assistance or approval.

This first "moment" of translation, "problematization", involves the definition of the problem and its solution. The subsequent three moments are all oriented toward the achievement of this solution through the manipulation of other actors and intermediaries. The second moment, "interessement", involves "one entity attracting a second by coming between that entity and a third" [Callon, Law and Rip 1986]. Thus, interesting other actors signifies forging privileged relationships, a "system of alliances", between them and the translator by convincing them to accept the translator's definition of their identities and desires, to the exclusion of all other definitions. This may be achieved through "seduction or a simple solicitation" or, if necessary, through "pure and simple force". Ultimately, the purpose of interessement is to "corner the entities to be enrolled" [Callon 1986], in preparation for the third moment of translation, "enrolment", which involves putting into action the roles defined for the other actors during the problematization phase. At this juncture, to make the translation a success, the translator requires the cooperation of the other actors and intermediaries, who must enact the roles assigned to them. This requires a series of "multilateral negotiations, trials of strength and tricks" [Callon 1986]. However, these negotiations can only be carried out with a few representatives of each actor-network to be enrolled. Finally, then, the fourth moment of translation is "mobilization", in which these representatives attempt to convince the other members of their constituency to enact the roles agreed on their behalf. At every stage, seduced or forced to follow the itinerary thus laid out for them, actors and intermediaries experience "displacement", the literal movement necessary to "solidify" the actor-worlds and thus render the translation successful [Callon 1986].

In sum, these four characteristics of the Actor Network Theory discussed in the previous section are the reasons why ANT can be the possible solution to the problem of describing new product development processes. The heterogeneity of the new product development participants is the source of the first and second reason. The advantage of ANT is that it has the ability to represent the heterogeneity of networks. This expression power of ANT is also able to represent human actors as well as non-human actors such as goals, customers, platforms and so on. The third reason is that the ANT can express the nested networks of actors. Since the emerging product development characteristics have various hierarchical levels, which are described as networks, ANT is able to be an alternative theory to represent the new product development process properly. The fourth reason is the expression ability of 'translation' of the ANT. Since the dynamic change of participants and role status in the new product development process is a unique characteristic, the ability to represent dynamic changes is necessary. By modeling the changes in the emerging product development process with the 'Translation' in ANT, the steps of those changes can be represented.

2.4.2. Modeling of Actor Network Theory

Socio-Technical Graph: The effort to modeling Actor Network Theory was started by Latour and his colleagues in early 1990s. This research focused on showing the principle of the social-technical graphs, generalization and operationalization of scientific controversies. The first task was to make more precise the definition of the two dimensions, which would be used as the 'latitude' and 'longitude' for the mapping process. The first [syntagmatic] dimension defined how many different elements might be held together in a meaningful assemblage, while the second [paradigmatic] dimension defines the meaningful substitutions that might be done at each

point along the syntagm. The first dimension defined association, and the second substitution – or, still more synthetically, AND and OR. They also tried to calculate the indicators with size, the number of elements such as allies and new actors. Based on the number of new actors and size, they calculated 'Index of Negotiation'. However, since this index and calculation were limited to the numbers of actors, it could not involve the characteristics of actors and allies in the network.

Actor-network procedure: Pavlovic and Meadows [2012] proposed actor-networks as a formal model of computation in heterogenous networks of computers, humans and their devices, where these new procedures run. When networks involved heterogeneous nodes, and heterogeneous communication channels, then the diverse resources leaded to different powers. In addition, configurations called actor-networks to adjust adjacent actors including themselves were introduced. An agent who participated in a configuration was an actor, in the sense that she played a particular role assigned to it by a particular network procedure. As networks spread and diversify, it was becoming increasingly important, and increasingly difficult, to assure that procedures provided the desired actor and network behaviors. Towards this goal, they formalized the above intuitions about actor-networks, and built a framework for reasoning about their procedures.

They applied that the hierarchical structure of our actor-network formalism was alien to the spirit and the letter of original actor-network idea from Latour's work [2005]. But it was essential for the goals of their logical analyses, which were different from the goals of sociological analyses.

CHAPTER 3.

PARTICIPANT BEHAVOR ANALYSIS: FORMALISM WITH TRANSLATION OF ACTOR-NETWORK THEORY PERSPECTIVE

3.1. Introduction

This research presents a formalism for translation in actor network theory in order to apply the analogy to the processes of crowdsourcing design which are happening in crowdsourcing design threads. Current crowdsourcing design activities have shown the following procedures: (1) a product idea is initiated as a design project when a participant submits onto a crowdsourcing thread, (2) after an idea is submitted; the crowd participates through various methods, such as voting, commenting, and committing with their own knowledge, (3) after an idea is selected as a working-on item, it is posted in order to gather various types of contributions from the crowd (as simple as what color it should be, or as complicated as how to solve an engineering issue). In this stage, the crowd can provide opinions and solutions in specified categories, (4) an initiating participant (problem or product initiator) provides possible rewards for the contributing participations, and finally (5) after the design is realized as a product, the design project is completed and all the participants and the crowdsourcing platform use the specific design project to mobilize other possible participants to contribute to the future potential design projects.

The whole process explained above has been thought of as being in some way analogous to the processes of developing an actor network, translation, in actor network theory. The processes of actor network theory are summarized in Table 3.1 with the perspective of ‘translation’. As we discussed in the previous section, translation consists of four moments with

sub processes to complete each moment. In this section, we represent the changes of processes and elements in crowdsourcing design activities with the perspectives of 'Translation' in Actor-Network Theory; to understand the detailed design activities in a crowdsourcing environment; and to embed the formalized processes and elements to computational applications.

In order to Four 'Moments' of translation proposed by Callon (1986) to describe the processes of how actor networks have been developed- Problematization (***P***), Interessement (***I***), Enrolment (***E***), and Mobilization (***M***). Each moment has a couple of detailed 'processes' to conduct and complete itself. Especially, 'Activities' such as negotiation (*N*), trials of strength (*S*), and tricks (*T*) are specific jobs which are conducted in interessement and enrolment.

Table 3.1 explains the details of Moment, Process, and Activity with notations which are used in this research.

Table 3.1 Processes in Translation of Actor Network Theory

Moments	**Processes**	**Notation**
Problematization	Interdefining actors	P^{IA}
	Building and setting up an obligatory passage points	P^{OPP}
Interessement	An entity attempts to impose the identity of the other actors	I^{AI}
	An entity attempts to stabilize the identity of the other actors	I^{AS}
Enrolment	An entity finalizes to impose the identity of the other actors	E^{FI}
	An entity finalizes to stabilize the identity of the other actors	E^{FS}
Mobilization	Building consensus among participants and other entities who play roles as representatives	M^{CB}
	Represent the built network to mobilize	M^{RN}
Activities of Interessement and Enrolment	Multilateral negotiation	N
	Trial(s) of strength (that accompany the interessements and enable them to succeed)	S
	Trick(s) (that accompany the interessements and enable them to succeed)	T

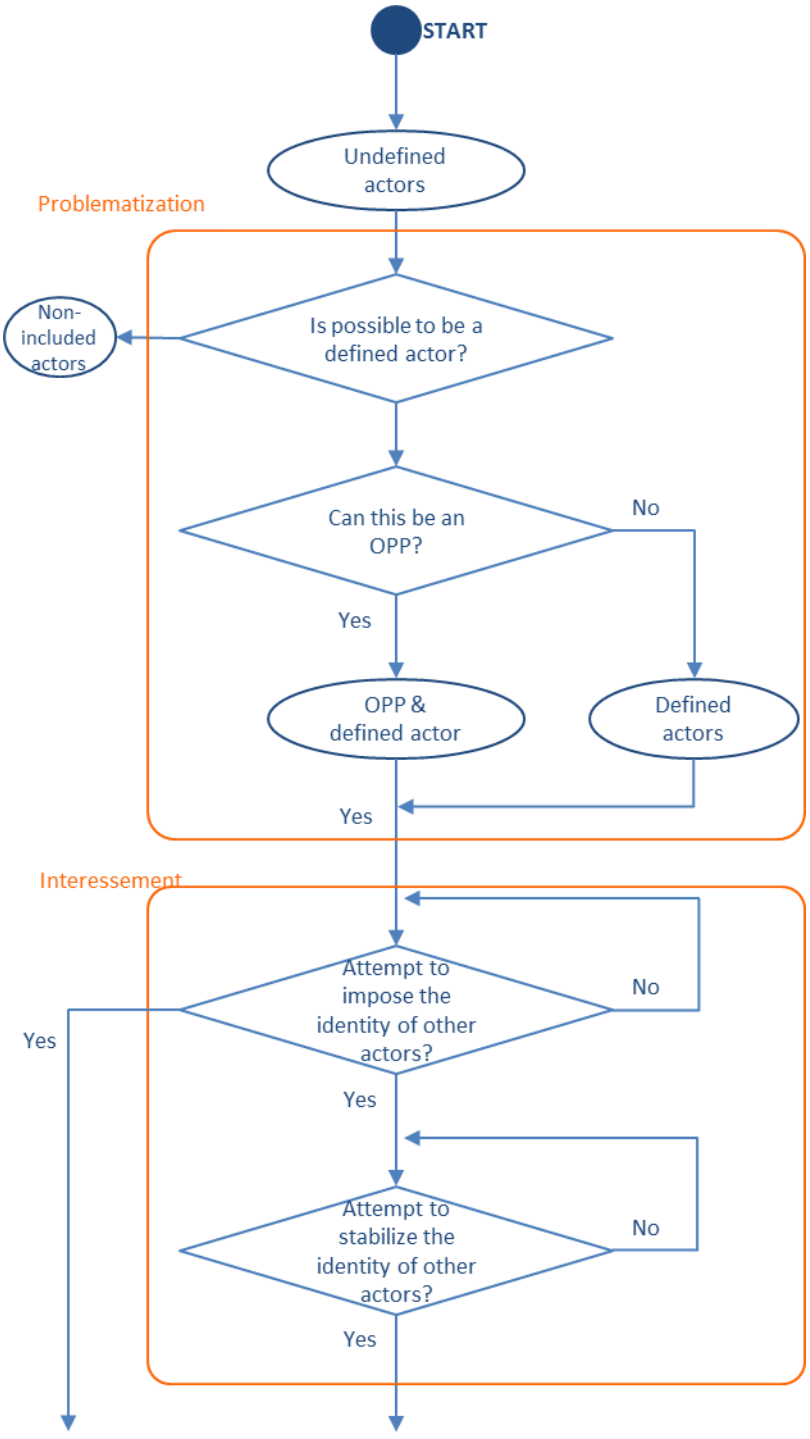

Figure 3.1 Flowchart to explain the processes of translation in Actor Network Theory – Problematization and Interessement

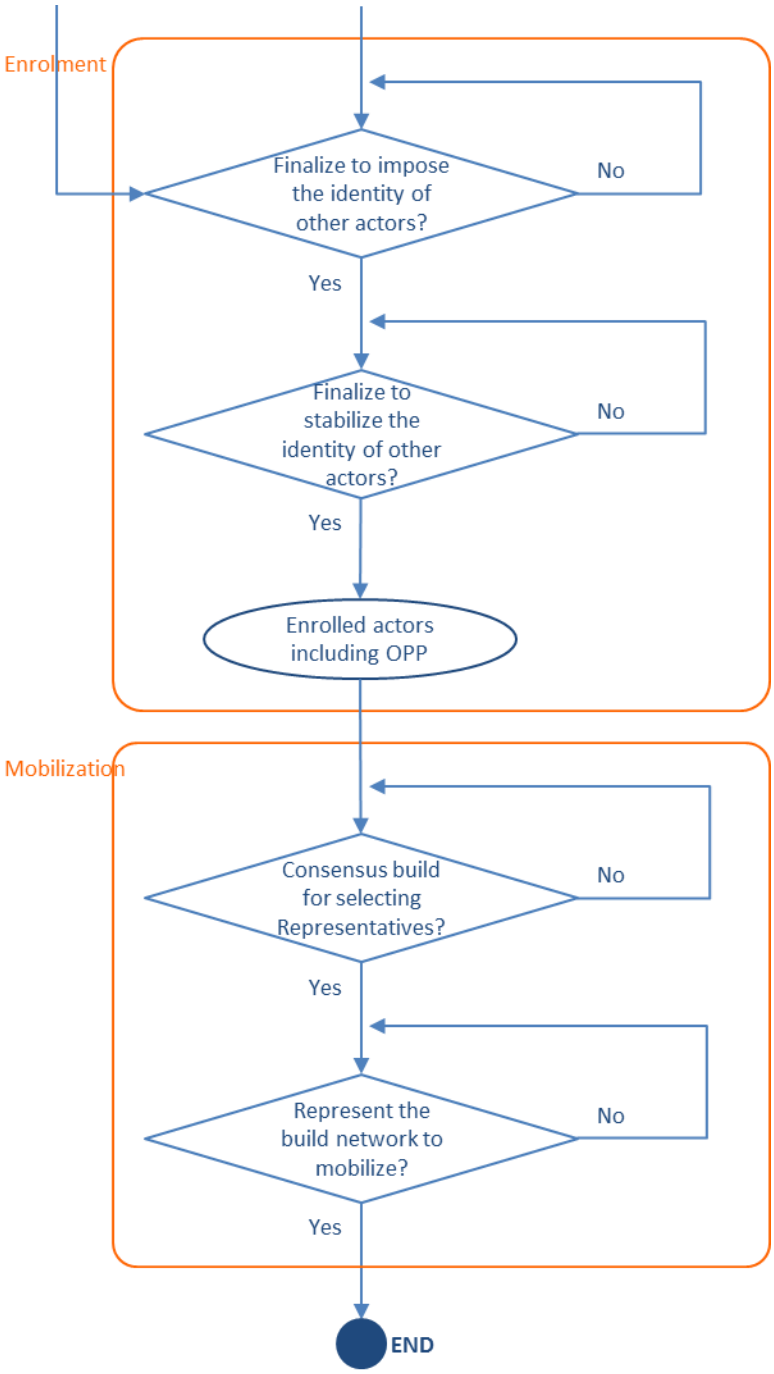

Figure 3.2 Flowchart to explain the processes of translation in Actor Network Theory – Enrolment and Mobilization

3.2. Perspectives

In order to formulize translation of actor network theory, two describable perspectives should be considered; *Process* and *Element*. The first perspective is the '*process*' view. Each process is the specified activities which consist of a moment in translation. For example, Problematization has two (sub-) processes such as 'interdefining actors' and 'set an obligatory passage point among actors'. After completing those two (sub-) processes, the moment, 'problematization' is completed and proceed to the next moment, 'Interessement'. Therefore, with process perspective, the formalism should be represented the occurrence and completion of (sub-) processes on Figure 3.3. The second perspective is '*element*' view. With this perspective, the formulation focuses on the changes of element in each (sub-) process. Elements in translation of actor network theory means that the pieces of features which can be used to communicate to each other, to negotiate with other actors or participants, and so on. Basically, translation in crowdsourcing design is the process of refining design features as elements to extract or generate concepts from participants' contributions. Participants in a crowdsourcing design thread communicate with each other through the design features which are described or mentioned in the thread to negotiate, persuade, or compel with each other. The changes of the number of elements by the pieces of the design feature or information is the describing point to identify that the process has occurred or is completed. Translation of actor network theory with process perspective is illustrated in Figure 3.3.

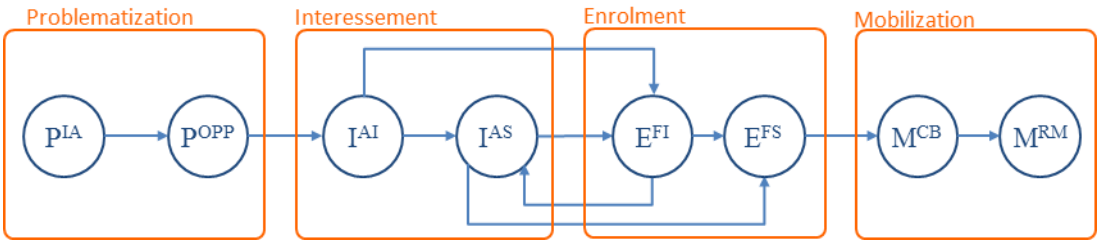

Figure 3.3 Translation of Actor Network Theory with process perspective

3.3. Formalism

3.3.1. Process

For the proposed processes of translation in actor network, this research defines key operations as follows:

Operators

A$[\![O]\!]$, where A is a moment or a (sub-) process and $[\![O]\!]$ is occurred, not completed the process A.

A$[\![C]\!]$: where A is a moment or a (sub-) process and $[\![C]\!]$ is completed the process A.

A$[\![S]\!]$: where A is a moment or a (sub-) process and $[\![C]\!]$ is started the process A.

$$process\ A[\![S]\!] \wedge \neg process\ A[\![C]\!] \vdash process\ A[\![O]\!] \quad (3.1)$$

The relationship of operators $[\![S]\!], [\![C]\!], [\![O]\!]$ is shown in equation (3.1). If a process A is started and not completed, then the process A is in the procedure of process A occurred.

***Problematization* (*P*)**

In order to complete the moment of problematization, two (sub-) processes should be conducted: interdefining actors (P^{IA}) and building and setting up obligatory passage points (P^{OPP}).

Definitions and relevant equations of process in problematization are shown below:

P^{IA}: Interdefining actors

P^{OPP}: Building and setting up an Obligatory Passage Points

$$P_{ij}^{IA}[\![C]\!] \wedge P_{ij}^{OPP}[\![C]\!] \vdash \mathbf{P}_{ij}[\![C]\!] \quad (3.2)$$

$$^{\forall}P_{ij}^{IA}[\![O]\!] \wedge {}^{\nexists}P_{ij}^{OPP}[\![O]\!] \vdash P_{ij}^{IA}[\![C]\!] \quad (3.3)$$

$$^{\forall}P_{ij}^{IA}[\![O]\!] \wedge {}^{\exists}P_{ij}^{OPP}[\![C]\!] \vdash P_{ij}^{OPP}[\![C]\!] \quad (3.4)$$

$$^{\forall}P_{ij}^{IA}[\![C]\!] \wedge {}^{\exists}P_{ij}^{OPP}[\![C]\!] \vdash \mathbf{P}_{ij}[\![C]\!] \wedge \mathrm{I}_{ij}^{AI}[\![S]\!] \quad (3.5)$$

For all equation (2) ~ (5), $i = 1, \dots, m \in Z^{0,+}$ and j= $1, \dots, n \in Z^{0,+}$

In equation (3.2), if any actor i and j have defined each other and set obligatory passage points at least more than equal to one, the problematization is completed. If the (sub-) process of interdefining actors for all actors *i* and *j* have occurred but the OPP is not set up yet, then the process of interdefining actors is in progress (equation (3.3)). If the (sub-) process of interdefining actors for all actors *i* and *j* have *occurred* and any actors who set up as OPP exist at least more than equal to one, then the (sub-) process, P_{ij}^{OPP}, is completed (equation (3.4)). Equation (3.5) means that if P_{ij}^{IA} are *completed* for all actors *i* and *j* and any actors which set up

as OPP exist, then the problematization is completed and a (sub-) process of the interessement, 'Attempt to Impose the identity of the other actors' is started.

Interessement(*I*)

In order to complete the moment of interessement, two (sub-) processes should be conducted: an entity attempts to impose the identity of the other actors (I^{AI}) and an entity attempts to stabilize the identity of the other actors (I^{AS}). The difference between 'impose' and 'stabilize' is the identity of the other actors is identified by the commitment between the actors. The 'impose' is the stage of starting to show an actors' own interest. On the other hand, the 'stabilize' is the stage of starting to understand other actors' own interest. In order to distinguish the enrolment, the actors do not recognize the benefits or specified roles in the actor network yet at the interessement. Definitions and relevant equations of process in interessement are shown below:

I^{AI}: An entity attempts to impose the identity of the other actors

I^{AS}: An entity attempts to stabilize the identity of the other actors

$$I_{ij}^{AI}[\![S]\!] \wedge \neg I_{ij}^{AI}[\![C]\!] \vdash I_{ij}^{AI}[\![O]\!] \quad (3.6)$$

$$^{\exists} I_{ij}^{AI}[\![C]\!] \vdash I_{ij}^{AS}[\![S]\!] \vee E_{ij}^{FI}[\![S]\!] \quad (3.7)$$

$$I_{ij}^{AS}[\![O]\!] \wedge \neg I_{ij}^{AS}[\![C]\!] \vdash I_{(i+1)j}^{AS}[\![S]\!] \vee I_{i(j+1)}^{AS}[\![S]\!] \quad (3.8)$$

$$^{\exists} I_{ij}^{AS}[\![C]\!] \vdash \mathbf{I}_{ij}[\![C]\!] \wedge (E_{ij}^{FI}[\![S]\!] \vee E_{ij}^{FS}[\![S]\!]) \quad (3.9)$$

For all equation (6) ~ (9), $i = 1, \dots, m \in Z^{0,+}$ and j= $1, \dots, n \in Z^{0,+}$

As similar to equations (3.2) to (3.5), the (sub-) processes of interessement can be represented with 'occur', 'complete', and 'start' operators. If actor *i* and *j* are in progress of being started but not completed, we can recognize that the attempts to impose the identity of other actors have occurred. In equation (3.7), if the attempts to impose the actor i or j's identity is completed, actor *i* and *j* start to attempt to stabilize the relationship between them or start to finalize to impose other actors' identities. If the attempt to stabilize the identity between actor *i* and *j* is not completed, the attempt moves to other actor i+1 and starts another attempt between actor *i+1* and *j* (equation (3.8)). Since the interessement is interwined with the enrolment as we referred in the section 3.2., the completion of processes in the interessement can trigger the start of (sub-) process of the enrolment, $E_{ij}^{FI}[\![S]\!] \vee E_{ij}^{FS}[\![S]\!]$, (equation (3.9)).

Enrolment(E)

Though (sub-) processes of the enrolment are quite similar to those of the interessement, some differences exist. First, enrolment is the moment of finalizing the imposition and the stabilization which have been started or occurred in the interessement. The second difference is that the benefits are revealed to accomplish the purpose of finalization of imposition or stabilization. Since enrolment is the moment of identifying the actors' roles, the roles should be explained with benefits after conducting their own roles successfully.

E^{FI}: An entity finalizes to impose the identity of the other actors

E^{FS}: An entity finalizes to stabilize the identity of the other actors

$$E_{ij}^{FI}[\![O]\!] \wedge \neg E_{ij}^{FI}[\![C]\!] \vdash (E_{(i+1)j}^{FI}[\![S]\!] \vee E_{i(j+1)}^{FI}[\![S]\!]) \vee (I_{(i+1)j}^{AS}[\![S]\!] \vee I_{i(j+1)}^{AS}[\![S]\!]) \quad (3.10)$$

$$^{\exists}E_{ij}^{FI}[\![C]\!] \vdash E_{ij}^{FS}[\![S]\!] \quad (3.11)$$

$$E_{ij}^{FS}[\![O]\!] \wedge \neg E_{ij}^{FS}[\![C]\!] \vdash E_{(i+1)j}^{FS}[\![S]\!] \vee E_{i(j+1)}^{FS}[\![S]\!] \quad (3.12)$$

$$^{\exists}E_{ij}^{FS}[\![C]\!] \vdash \mathbf{E}_{ij}[\![C]\!] \wedge M_{ij}^{CB}[\![S]\!] \quad (3.13)$$

For all equation (10) ~ (13), $i = 1, \dots, m \in Z^+$ and j= $1, \dots, n \in Z^+$

If the finalization of imposition is occurred and not completed yet, the same process is restarted between another actor *(i+1)* or *(j+1)* and *i* and *j* or the attempt to stabilize with other actors is restarted (equation (3.10)). If actor i and j exist which completes the finalization of imposition, then the finalization of stability in the enrolment is started (equation (3.11)). Equation (3.12) explains that if the finalization of stabilization has occurred but not completed yet, the same process is restarted between another actor *(i+1)* or *(j+1)*. If actor *i* and *j* exist which completes the (sub-) process of finalizing to stable the identity of other actors, the whole enrolment is completed and the consensus building process to choose representatives of the actor network (M_{ij}^{CB}) is started.

Activities in sub-process of Interessement and Enrolment

According to the Callon's work (1986), negotiation, trials of strength, and tricks are used to accomplish the imposition or the stabilization which are conducted in the interessement and

the enrolment (equation (3.14)). If at least one of the three activities has not been occurred and conducted successfully, the attempt of imposition or stabilization cannot be completed (equation (3.15), (16)). Since the three activities are also applied and happen at the moment of the enrolments similar to the interessement, equation (3.17), (3.18), and (3.19) can be drawn similar to equation (3.14), (3.15), and (3.16) respectively.

Negotiation (N): Multilateral negotiation

Trials of Strength (S): Trial(s) of strength (that accompany the interessements and enable them to succeed the Enrolments)

Tricks (T): Trick(s) (that accompany the interessements and enable them to succeed the Enrolments)

$$N_{ij}^{I}[\![O]\!] \vee S_{ij}^{I}[\![O]\!] \vee T_{ij}^{I}[\![O]\!] \vdash I_{ij}^{AI}[\![O]\!] \vee I_{ij}^{AS}[\![O]\!] \quad (3.14)$$

$$I_{ij}^{AI}[\![O]\!] \wedge (N_{ij}^{I}[\![C]\!] \vee S_{ij}^{I}[\![C]\!] \vee T_{ij}^{I}[\![C]\!]) \vdash I_{ij}^{AI}[\![C]\!] \quad (3.15)$$

$$I_{ij}^{AS}[\![O]\!] \wedge (N_{ij}^{I}[\![C]\!] \vee S_{ij}^{I}[\![C]\!] \vee T_{ij}^{I}[\![C]\!]) \vdash I_{ij}^{AS}[\![C]\!] \quad (3.16)$$

$$N_{ij}^{E}[\![O]\!] \vee S_{ij}^{E}[\![O]\!] \vee T_{ij}^{E}[\![O]\!] \vdash E_{ij}^{FI}[\![O]\!] \vee E_{ij}^{FS}[\![O]\!] \quad (3.17)$$

$$E_{ij}^{FI}[\![O]\!] \wedge (N_{ij}^{E}[\![C]\!] \vee S_{ij}^{E}[\![C]\!] \vee T_{ij}^{E}[\![C]\!]) \vdash E_{ij}^{FI}[\![C]\!] \quad (3.18)$$

$$E_{ij}^{FS}[\![O]\!] \wedge (N_{ij}^{E}[\![C]\!] \vee S_{ij}^{E}[\![C]\!] \vee T_{ij}^{E}[\![C]\!]) \vdash E_{ij}^{FS}[\![C]\!] \quad (3.19)$$

For all equation (14) ~ (19), $i = 1, \dots, m \in Z^{+}$ and j= $1, \dots, n \in Z^{+}$

Mobilization (***M***)

The (sub-) processes of Moblization are ‘builidng consensus to choose representatives’ and ‘representing and promoting the built network to mobilize other actors in other actor networks. Since consensus building should occur and be completed with internal actors of the built actor network, the consensus building between actors happens until the process is completed (equation (3.20)).

M^{CB}: Building consensus among participants and other entities who play roles as representatives

M^{RN}: Represent the built network to mobilize

$$M_{ij}^{CB}[\![O]\!] \wedge \neg M_{ij}^{CB}[\![C]\!] \vdash M_{(i+1)j}^{CB}[\![S]\!] \vee M_{i(j+1)}^{CB}[\![S]\!] \quad (3.20)$$

$$^{\exists} M_{ij}^{CB}[\![C]\!] \vdash M^{RN}[\![S]\!] \quad (3.21)$$

For all equation (20) ~ (21), $i = 1, \dots, m \in Z^{+}$ and j= $1, \dots, n \in Z^{+}$

Since the objects of the sub process (M^{RN}) exist outside of current actor network, M^{RN} and $\boldsymbol{M}$ are open ended activities in universe space for all translations (equation (21)).

3.3.2. Element

The flow of the processes that occur in translation of actor network theory is formulated in the section 3.3.1. However, every process should be identified with features and information of actors as elements. In order to make the element perspective simple and clear, the assumption that each actor has two aspects, identification and information is applied and also those two

aspects are considered to compare the differences between processes (equations (3.22)-(3.27)). Since each actor network can have multiple actors as nested one, an identification of actor should be represented as a set (equation (3.22)).

a_i^{id}, a_j^{id}: A set of identification of actor *i* and *j* respectively	(3.22)
a_i^{info}, a_j^{info}: A set of features or specific information related to actor *i* and *j* respectively	(3.23)
A_i, A_j: Vector of identification and features of actor *i* or *j*	(3.24)
$A_i =< a_i^{\text{id}}, a_i^{\text{info}} >,\ A_i =< a_j^{\text{id}}, a_j^{\text{info}} >$, where $i, j = 1, 2, \dots, n \in \boldsymbol{Z}^+$	(3.25)
$a_i^{\text{id}} = \{u_0, u_1, u_2, \dots, u_k\}$, where $k \in \boldsymbol{Z}^+$	(3.26)
$a_i^{\text{info}} =< u_k^{\text{info}}, u_k^{\text{knowledge}} >$, where $k \in \boldsymbol{Z}^+$	(3.27)

Problematization

The differences between $P_{ij}^{IA}[\![O]\!]$ and $P_{ij}^{IA}[\![C]\!]$ are represented with two aspects: (1) an intersect exists between identifications of actor *i* and *j*, and (2) the changes of number of elements between actor *i* and *j*. If there is no intersect of identifications between actor *i* and *j* and the sum of each actor i's and j's elements is same to the number of elements in the union of actor i and j's elements in the moment of problematization, the situation of the process of interdefining actors is occurred (equation (3.28)). On the other hand, if there exists any intersection of identifications between actor *i* and *j* and the sum of each actor *i*'s and *j*'s elements is greater than the number of elements in the union of actor i and j's elements, the situation of the process of interdefining actors is completed (equation (3.29)).

$$P_{ij}^{IA}[\![O]\!] := a_i^{\mathrm{id}} \cap a_j^{\mathrm{id}} = \emptyset \wedge \left|a_i^{\mathrm{info}}\right| + \left|a_j^{\mathrm{info}}\right| = \left|a_j^{\mathrm{info}} \cup a_j^{\mathrm{info}}\right| \quad (3.28)$$

$$P_{ij}^{IA}[\![C]\!] := a_i^{\mathrm{id}} \cap a_j^{\mathrm{id}} \neq \emptyset \wedge \left|a_i^{\mathrm{info}}\right| + \left|a_j^{\mathrm{info}}\right| > \left|a_j^{\mathrm{info}} \cup a_j^{\mathrm{info}}\right| \quad (3.29)$$

$$P_{ij}^{OPP}[\![O]\!] := a_i^{\mathrm{id}} \cap a_j^{\mathrm{id}} = \emptyset \quad (3.30)$$

$$P_{ij}^{OPP}[\![C]\!] := a_i^{\mathrm{id}} \cap a_j^{\mathrm{id}} \neq \emptyset \wedge a_i^{\mathrm{id}} \cap a_j^{\mathrm{id}} \subseteq a_j^{\mathrm{id}} \quad (3.31)$$

For all equation (3.28) ~ (3.31), $i = 1, \dots, m \in Z^+$ and j= $1, \dots, n \in Z^+$

The situation that an OPP has occurred among actors is represented that no intersection between any actor *i, j* with their identification. Also, a set up to build an OPP is completed means that the intersection between actor *i* and *j* should be a subset of an actor in current actor network (equation (31)).

Interessement

According to the described processes in section 3.1., four combinatory situations are possible in the interessement: (1) occurrence of an attempt to impose the identity of other actors, (2) completion of an attempt to impose the identity of other actors, (3) occurrence of an attempt to stabilize the identity of other actors and (4) completion of an attempt to stabilize the identity of other actors. One of actors in the first two situations, *occurrence of an attempt to impose* and *completion of an attempt to impose* should be the OPP, since the OPP induces other actors to participate in a current actor network. If there is no intersect of identifications between actor *i* and *j* and the sum of each actor i's and j's elements is same to the number of elements in the union of actor i and j's elements in the interessement, the situation of the process of attempt to impose the identity of other actors is occurred (equation (3.32)). On the other hand, if there exists

any intersect of identifications between actor *i* and *j* and the sum of each actor *i*'s and *j*'s elements is greater than the number of elements in the union of actor i and j's elements, the situation of the process of attempt to impose the identity of other actors is completed (equation (3.33)).

The main difference between *impose* and *stabilize* in the interessement is that the stabilization occur between any actors including OPP, but imposition can happen between OPP and another actor. If one of the actors in the stabilization is OPP, the situation is the same as equation (3.32) and (3.33). Meanwhile, if no OPP is involved, the sum of numbers of the intersected elements with OPP and actor *i* and *j* should be greater than and equal to the number of the union of OPP's information elements and the intersected information elements between actor *i* and *j* (equation (3.34) and (3.35)). If the completion of attempt to stabilize the identity of other actors is led by OPP, the situation is the same with $I_{ij}^{AS}[\![C]\!]$ and $I_{ij}^{AS}[\![O]\!]$ (equation (3.36)). If no OPP is involved and in order to complete this situation, the sum of numbers of the intersected elements with OPP and actor *i* and *j* should be greater than the number of the union of OPP's information elements and the intersected information elements between actor *i* and *j* (equation (3.37)).

Occurrence of an attempt to impose the identity of other actors

$$I_{ij}^{AI}[\![O]\!] \coloneqq a_i^{\text{id}} \cap a_j^{\text{id}} \neq \emptyset \wedge (a_i^{\text{info}} \cap a_j^{\text{info}} = \emptyset \vee |a_i^{\text{info}}| + |a_i^{\text{info}}| = |a_i^{\text{info}} \cup a_i^{\text{info}}|) \quad (3.32)$$

, where i=*opp*, j = 1, …, n (except *opp*)

Completion of an attempt to impose the identity of other actors

$$I_{ij}^{AI}[\![C]\!] \coloneqq a_i^{\text{id}} \cap a_j^{\text{id}} \neq \emptyset \wedge (a_i^{\text{info}} \cap a_j^{\text{info}} = \emptyset \vee |a_i^{\text{info}}| + |a_i^{\text{info}}| \geq |a_i^{\text{info}} \cup a_i^{\text{info}}|) \quad (3.33)$$

, where i=*opp*, j = 1, …, n (except *opp*)

Occurrence of an attempt to stabilize the identity of other actors

$$I_{ij}^{AS}[\![O]\!] = I_{ij}^{AI}[\![C]\!],\ i = opp \tag{3.34}$$

$$\left(a_i^{\text{id}} \cap a_{opp}^{\text{id}}\right) \cup \left(a_j^{\text{id}} \cap a_{opp}^{\text{id}}\right) = \emptyset \ \wedge \left[\left|a_i^{\text{info}} \cap a_{opp}^{\text{info}}\right| + \left|a_j^{\text{info}} \cap a_{opp}^{\text{info}}\right| \geq \left|\left(a_i^{\text{info}} \cap a_{opp}^{\text{info}}\right) \cup \left(a_j^{\text{info}} \cap a_{opp}^{\text{info}}\right)\right|\right], \text{ if } i \neq opp \tag{3.35}$$

Completion of an attempt to stabilize the identity of other actors

$$I_{ij}^{AS}[\![C]\!] = I_{ij}^{AS}[\![O]\!] = I_{ij}^{AI}[\![C]\!], \text{ if } \ i = opp \tag{3.36}$$

$$I_{ij}^{AS}[\![C]\!] \coloneqq \left(a_i^{\text{id}} \cap a_{opp}^{\text{id}}\right) \cup \left(a_j^{\text{id}} \cap a_{opp}^{\text{id}}\right) \neq \emptyset \ \wedge \left[\left|a_i^{\text{info}} \cap a_{opp}^{\text{info}}\right| + \left|a_i^{\text{info}} \cap a_{opp}^{\text{info}}\right| > \left|\left(a_i^{\text{info}} \cap a_{opp}^{\text{info}}\right) \cup \left(a_i^{\text{info}} \cap a_{opp}^{\text{info}}\right)\right|\right], \text{ if } \ i \neq opp \tag{3.37}$$

For all equation (32) ~ (37), $i = 1, \ldots, m \in Z^+$ and j= $1, \ldots, n \in Z^+$

Enrolment

Similar to the interessement, four combinatory situations are able to occur in the enrolment according to the description in section 3.1: (1) occurrence of finalization to impose the identity of other actors, (2) completion of finalization to impose the identity of other actors, (3) occurrence of finalization to stabilization of the other actors' identities, and (4) completion of finalization to stabilization of the other actors' identities.

The main characteristic of the enrolment compared to the interessement is that all the element information associated with actors is inherited from the interessement. Also, the difference between '*attempt*' and '*finalization*' between them is not significant, because those

two situations can sometimes occur at the same time by cases. For those two reasons, the element situations in enrolment seem to be similar to the interessement [Callon, 1986]. However, the actors including OPP can finalize other actors' identity by sharing common element information with each other. Equations (3.38) to (3.41) describe the element situations in the enrolment. Since the elements in $E_{ij}^{FI}[\![O]\!]$ are inherited from $I^{AI}[\![O]\!]$ and $I^{AS}[\![O]\!]$, the element information regarding to numbers should be included (equation (3.38)). In the same manner, $E_{ij}^{FI}[\![C]\!]$ includes the element information of $I^{AI}[\![C]\!]$ and $I^{AS}[\![C]\!]$ additionally (equation (3.39)). Since the preceding processes of $E_{ij}^{FS}[\![O]\!]$ are $I^{AS}[\![O]\!]$ and $E^{FI}[\![O]\!]$, that information is included in equation (3.40). To complete $E_{ij}^{FS}[\![O]\!]$ as $E_{ij}^{FS}[\![C]\!]$, the element information of $I^{AS}[\![C]\!]$ and $E^{FI}[\![C]\!]$ are also included (equation (3.41)).

Occurrence of finalization to impose the identity of other actors

$$E_{ij}^{FI}[\![O]\!] \coloneqq a_i^{\mathrm{id}} \cap a_j^{\mathrm{id}} \neq \emptyset \wedge \left[(a_i^{\mathrm{info}} \cap a_j^{\mathrm{info}} \neq \emptyset) \vee (\left|a_i^{\mathrm{info}}\right| + \left|a_j^{\mathrm{info}}\right| \geq (\left|(a_i^{\mathrm{info}} \cup a_j^{\mathrm{info}})^{I^{AI}[\![O]\!]}\right| \vee \left|(a_i^{\mathrm{info}} \cup a_j^{\mathrm{info}})^{I^{AS}[\![O]\!]}\right|) \geq \left|a_i^{\mathrm{info}} \cup a_j^{\mathrm{info}}\right|\right] \quad (3.38)$$

Completion of finalization to impose the identity of other actors

$$E_{ij}^{FI}[\![C]\!] \coloneqq a_i^{\mathrm{id}} \cap a_j^{\mathrm{id}} \neq \emptyset \wedge \left[(a_i^{\mathrm{info}} \cap a_j^{\mathrm{info}} \neq \emptyset) \vee (\left|a_i^{\mathrm{info}}\right| + \left|a_j^{\mathrm{info}}\right| > (\left|(a_i^{\mathrm{info}} \cup a_j^{\mathrm{info}})^{I^{AI}[\![O]\!]}\right| \vee \left|(a_i^{\mathrm{info}} \cup a_j^{\mathrm{info}})^{I^{AS}[\![O]\!]}\right|) > (\left|(a_i^{\mathrm{info}} \cup a_j^{\mathrm{info}})^{I^{AI}[\![C]\!]}\right| \vee \left|(a_i^{\mathrm{info}} \cup a_j^{\mathrm{info}})^{I^{AS}[\![C]\!]}\right|) > \left|a_i^{\mathrm{info}} \cup a_j^{\mathrm{info}}\right|\right] \quad (3.39)$$

Occurrence of finalization to stabilization the identity of other actors

$$E_{ij}^{FS}[\![O]\!] \coloneqq a_i^{\mathrm{id}} \cap a_j^{\mathrm{id}} \neq \emptyset \wedge \left[(a_i^{\mathrm{info}} \cap a_j^{\mathrm{info}} \neq \emptyset) \vee (\left|a_i^{\mathrm{info}}\right| + \left|a_j^{\mathrm{info}}\right| \geq (\left|(a_i^{\mathrm{info}} \cup a_j^{\mathrm{info}})^{I^{AS}[\![O]\!]}\right| \vee \left|(a_i^{\mathrm{info}} \cup a_j^{\mathrm{info}})^{E^{FI}[\![O]\!]}\right|) \geq \left|a_i^{\mathrm{info}} \cup a_j^{\mathrm{info}}\right|\right] \quad (3.40)$$

Completion of finalization to stabilization the identity of other actors

$$E_{ij}^{FS}[\![C]\!] \coloneqq a_i^{\text{id}} \cap a_j^{\text{id}} \neq \emptyset \wedge \left[(a_i^{\text{info}} \cap a_j^{\text{info}} \neq \emptyset) \vee (\left|a_i^{\text{info}}\right| + \left|a_j^{\text{info}}\right| > (\left|(a_i^{\text{info}} \cup a_j^{\text{info}})^{I^{AS}[\![O]\!]}\right| \vee \left|(a_i^{\text{info}} \cup a_j^{\text{info}})^{E^{FI}[\![O]\!]}\right|) > (\left|(a_i^{\text{info}} \cup a_j^{\text{info}})^{I^{AS}[\![C]\!]}\right| \vee \left|(a_i^{\text{info}} \cup a_j^{\text{info}})^{E^{FI}[\![C]\!]}\right|) > \left|a_i^{\text{info}} \cup a_j^{\text{info}}\right|\right] \quad (3.41)$$

For all equation (3.38) ~ (3.41), $i = 1, \dots, m \in Z^+$ and j= $1, \dots, n \in Z^+$

Mobilization

Actually, by $E_{ij}^{FS}[\![C]\!]$, all activities to develop concepts in crowdsourcing design are completed.

Activities, that occur in Mobilization, are related to enlarge the current 'network' itself for starting the next Translation, in this research for developing another product (design) concept.

Since $M_{ij}^{CB}[\![O]\!]$ and $M_{ij}^{CB}[\![C]\!]$ are conducted based on 'pre-consensus', 'promises', 'policies' and so on, it is difficult to generalize with a formal representation.

In this case, total earning of PI, promotion in Quirky.com, and the number of followers of PI can also replace $M^{RN}[\![O]\!]$.

Since $M^{RN}[\![O]\!]$ is an open-ended activity for enlarging the network, $M^{RN}[\![C]\!]$ is not able to exist.

3.4. Validation

In this section, a case is provided to illustrate how the proposed actor network-based framework can be used to represent crowdsourcing design processes. The case chosen from a

well-known crowdsourcing design service platform, Quirky.com, and a representative design project, Pivot Power, were selected. Details of 'Pivot Power' are described in section 3.4.1. Not to be confused about the term of actor here, 'participant' is replaced the term 'actor' in the previous section.

3.4.1. Pivot Power

'Pivot Power' project was initiated by a participant (idea generator) and 50 participants were involved. By total 51 participants (U00~U50), 74 comments were provided to develop a design concept for pivot power. After being successfully commercialized in the market, the pivot power has brought more than $527,353 to idea generator and $871,407 to the community group which contributed to building the idea as a conceptual design and eventually a real commercialized product [Quirky.com: 2014a, 2014b]. It was chosen as a top selling item of Quirky.com by Wall Street Journal [Wall Street Journal, 2014]. Screenshots of pivot power are shown in Figure 3.4 (a), (b), and (c). Figure 3.4 is a commercialized product selling page. The initial idea generation is shown at Figure 3.5. It includes three rendering images to help crowds easy to understand what the initiator expect and propose. Figure 3.6 is a part of comments to enhance and to develop the initial idea with participants.

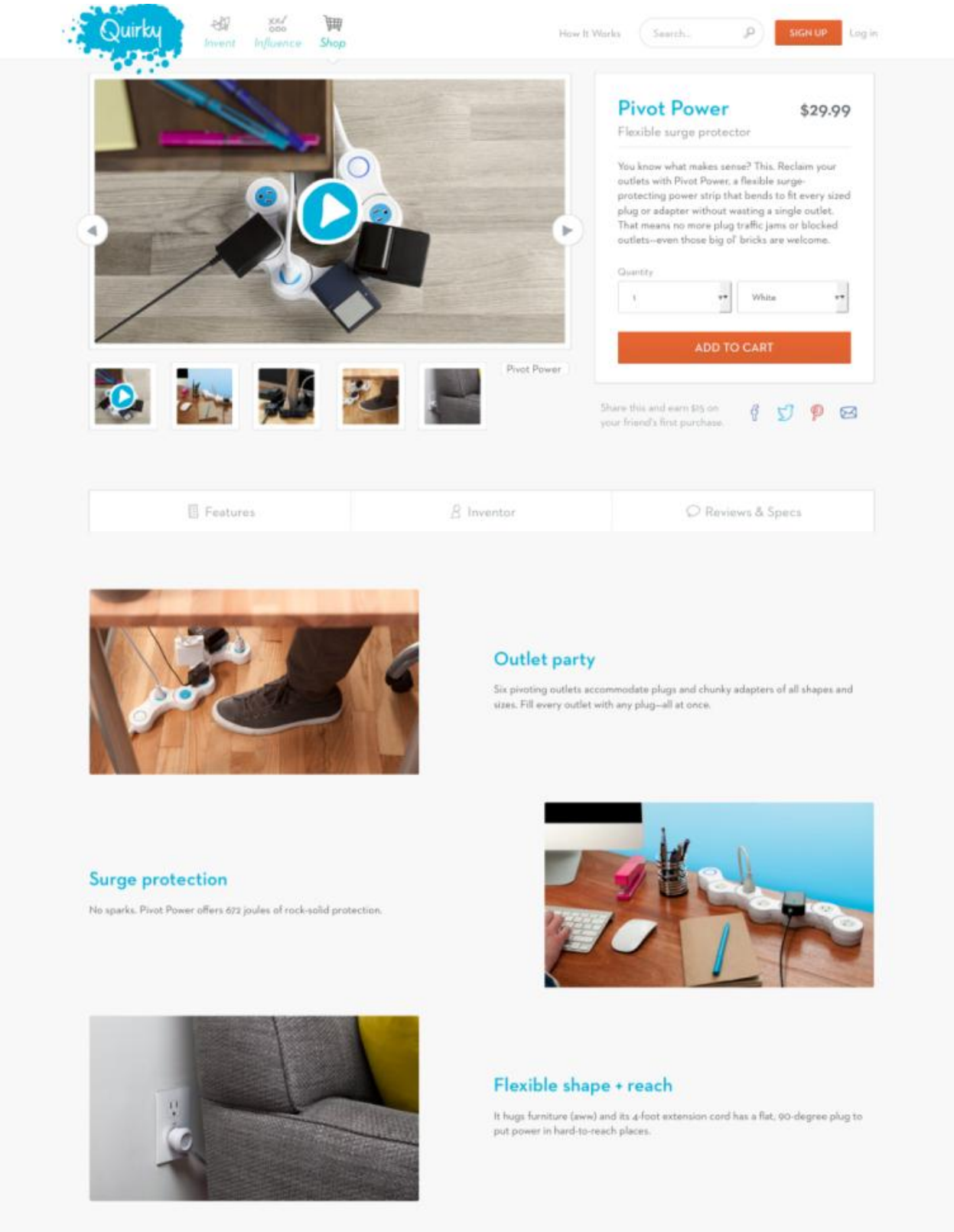

Figure 3.4 Commercialized product selling page of Pivot Power in Quirky.com

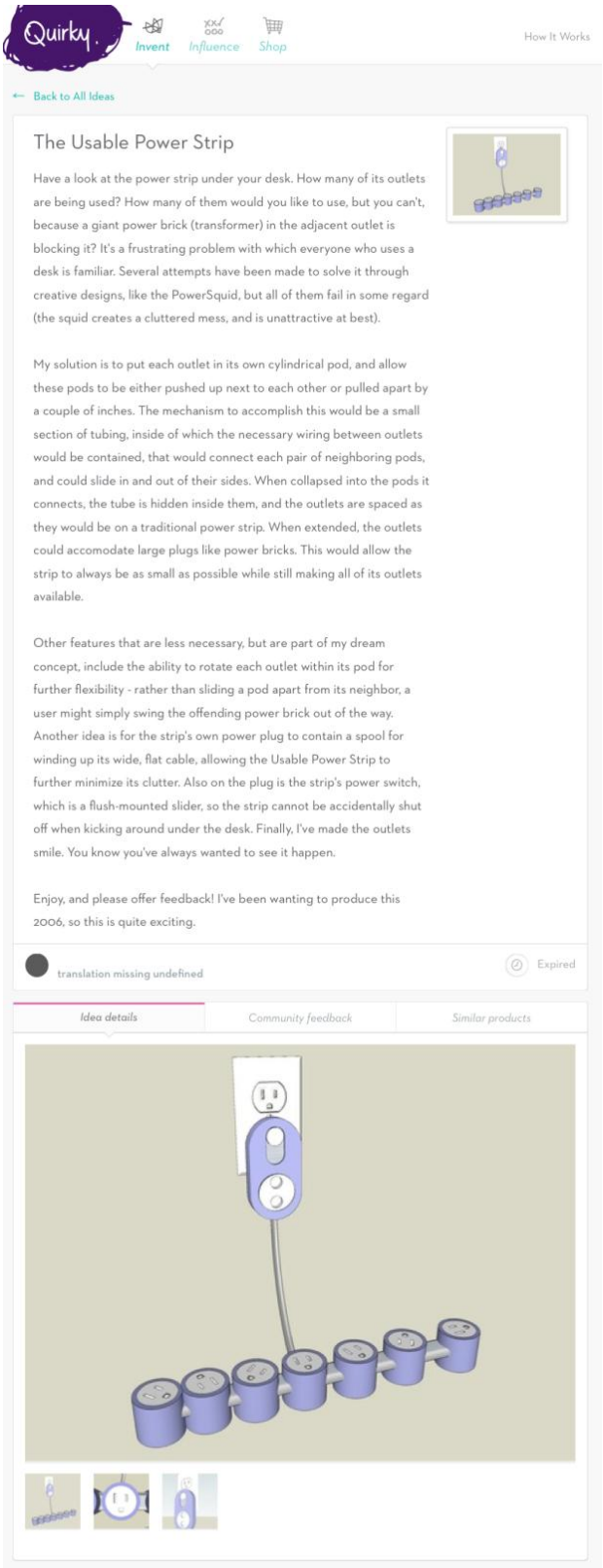

Figure 3.5 Initial idea generation page

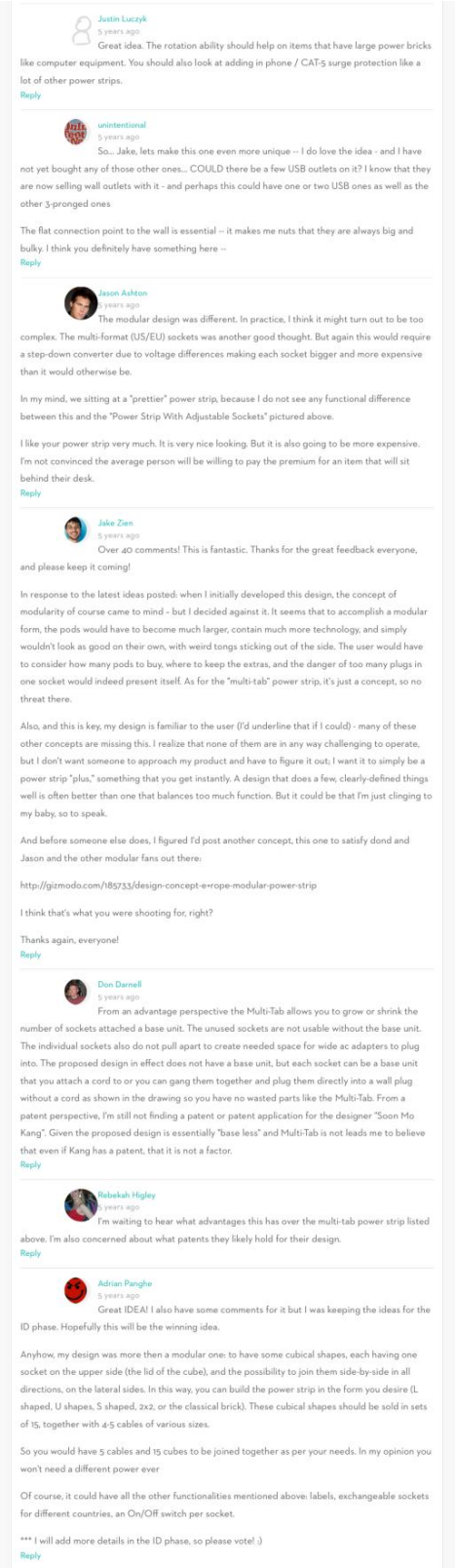

Figure 3.6 Partial screenshot of comments

3.4.2. Comparison of Translation between 'Scallops, Fishermen, and Scientists' (Callon, 1986) and 'Pivot Power' (quirky.com)

In order to validate that the developed process and element perspectives of translation in ANT, the comparison between the original reference of translation by Callon [Callon, 1986] and a crowdsourcing design activities in Quirky.com, Pivot Power is conducted in this section.

Before conducting a comparison, the clarification of the term, *actor*, is needed first. By Latour's work [Latour, 1992], actors are "entities that do things" [Latour, 1992, p. 241]. Also "The distinction between humans and non-humans, embodied or disembodied skills, impersonation or 'machination', are less interesting than the complete chain along which competences and actions are distributed." [Latour, 1992, p.243] Since any entities whether humans or not can be actors in ANT, the actors in crowdsourcing design environment can include not only humans but also other non-human elements such as design features, crowdsourcing design thread, and crowdsourcing design platform (Quirky.com). Particularly, human actors are called 'participants' in order to distinguish them from other non-human actors in crowdsourcing design.

The comparison table of the case of Scallops, Fishermen, and Scientists and crowdsourcing design of Pivot Power is shown in Table 3.2. In the next section, crowdsourcing design activities for Pivot Power are explained with the perspective of translation process-by-process.

Table 3.2 Comparison table: Case of Scallops, Fishermen, and Scientists and Crowdsouricng Design – Pivot Power

Moments	**(Sub-)processes**	**Case of Scallops, Fishermen, and Scientists**[1]	**Crowdsourcing Design - Pivot Power**[2]
Problematization	Interdefine actors	Define actors in the case - Three researchers - The fishermen of St. Brieuc - Scientific colleagues - The scallops of St. Brieuc (Pecten maximus)	Define actors in Pivot Power - Idea generator or problem initiator (PI) – U00 - Participants except PI – U01~U50 - Proposed idea in the thread in crowdsourcing (Pivot Power) - Features provided by crowdsourcing design platform (Quirky.com)
	Building and setting up an obligatory passage points	Obligatory passage point does pectin maximus attach itself	Crowdsourcing design thread which is created by idea generator (or problem initiator), participated in by other participants, and including information about all participants in crowdsourcing design platform (Quirky.com)
Interessement	An entity attempts to impose the identity of the other actors	Domestication of scallops e.g. "*The three researchers are inspired by a technique that had been invented by the Japanese. Towlines made up of collectors are immersed in the sea. Each collector carries a fine-netted bag containing a support for the anchorage of the larvae. These bags make it possible to assure the free flow of water and larvae while preventing the young scallops from escaping. The device also prevents predators from attacking the larvae. In this way the larvae are protected during the period when they have no defense: that is, when they have no shell. The collectors are mounted in a series on the line. The ends of the two lines are attached to floats that are kept in place by an anchorage system.*"	Actions in the thread by idea generator (or problem initiator) such as replying to participants' comments, referring features proposed by participants. e.g. *"I confess I've never owned the Squid (with this design in my head, I couldn't bring myself to buy it), but it seems to me that with it, what you gain in outlet count, you lose in organization. The idea of a power "strip" - an ordered, rigid row - makes more sense than the tangled knot of extension cords the Squid gives you. There's no way to become familiar with the Squid; each time it is used, the correct plug must be found. I would also imagine it creates a lot of clutter, and that its shape, essentially an egg with tails, makes it hard to find a position in which it will balance and rest comfortably under a desk.*

[1] All the italic font sentences with double quotation marks in the column of Case of Scallops, Fishermen, and Scientists are quoted from Callon, 1986.
[2] All the italic font sentences with double quotation marks in the column of Crowdsourcing Design are quoted from 'Pivot Power'. The link for this product is https://www.quirky.com/invent/24238/action/vote/query/view=trending&categories=all.

			Am I close?"
	An entity attempts to stabilize the identity of the other actors		Actions in the thread by idea generator (or problem initiator) such as appreciating and compliment participants' activities. These actions are intended not to loose participants' (other actors) interests to proposed product idea, pivot power. e.g. "*Over 40 comments! This is fantastic. Thanks for the great feedback everyone, and please keep it coming!*"
Enrolment	An entity finalizes to impose the identity of the other actors An entity finalizes to stabilize the identity of the other actors	e.g. "*The definition and distribution of roles (the scallops which anchor themselves, the fishermen who are persuaded that the collectors could help restock the Bay, the colleagues who believe in the anchorage) are a result of multilateral negotiations during which the identity of the actors is determined and tested.*"	In case of pivot power, finalization for the identity of the other actors happens at the same time with successful interessement.
Mobilization	Building consensus among participants and other entities who play roles as representatives	(Number of) Anchored larvae (Silent representative) Three researchers	Idea generator (or problem initiator) roles a representative if the product idea is developed to a concept design (and eventually a commercial product) successfully. Featured provided by crowdsourcing design platform such as total earnings, number of followers of idea generator (or problem initiator), and promotions in crowdsourcing design platform
	Represent the built network to mobilize	Three researchers published their study and presented it at a conference. e.g. "*Representation is also an issue in the researchers' transactions with the colleagues and fishermen. Properly speaking, it is not the scientific community which is convinced but a few colleagues who read the publications and attend the conference.*"	Total earnings of idea generator (or problem initiator) Number of followers of idea generator (or problem initiator) Frequency of exposed to other crowds as a promotion

Activities	Multilateral negotiation	e.g. "*To negotiate with the scallops is to first negotiate with the currents because the turbulences caused by the tide are an obstacle to the anchorage.*" "*The researchers must deal with other elements besides the currents.*"	Problem initiator and other participants communicate each other to decide which design features are more applicable and helpful for the proposed product idea
	Trial(s) of strength (that accompany the interessements and enable them to succeed)	e.g. "*The census done by the researcher also shows that the anchorages are more numerous 'between 5 meters above the sea floor and the sea floor itself. This is perhaps due to the depth as well as to the specific behavior of the scallops when they anchor: the larvae lets itself sink and anchors itself to the first obstacle that stops its descent."*"	Problem initiator and participants provide evidences to persuade and realize their ideas. For example, in order to avoid patent violation, participants provide similar patent lists as evidence.
	Trick(s) (that accompany the interessements and enable them to succeed)	"*The researchers are ready to make any kind of concession in order to lure the larvae into their trap.*"	NA

3.4.2.1. Four moments of Translation

Problematization

As the first process of problematization, the inter-definition between actors happens. In order to do this, Problem Initiator (PI) – U00, participants except PI – U01~U50, proposed idea in the thread in crowdsourcing (Pivot Power), and features and information provided by crowdsourcing design platform (Quirky.com). Even though the number of participants can be changed as time goes by, actors are defined themselves whether pre-defined or not in a crowdsourcing design thread. In case of features provided by crowdsourcing design platform, they are pre-defined before other actors are involved in this thread. However, when any actor starts to define other actors whatever they are, the process of inter-defining other actors occur.

The second process of problematization is to build and set up an obligatory passage points. In crowdsourcing design, a specific crowdsourcing design thread on Quirky.com can be an OPP. Since all the participants' activities have to happen within the crowdsourcing design thread in order to achieve their objective 'to develop a realized or commercialized product with initiated product idea'. Therefore crowdsourcing design thread created by idea generator (or problem initiator), participated in by other participants, and including information about all participants in crowdsourcing design platform (Quirky.com) should be an OPP.

Figure 3.7 shows that the problematization includes certain dynamic properties: "*it indicates the movements and detours that must be accepted as well as the alliances that must be forged.*" [Callon, 1986]. Idea generator or problem initiator (PI), participants except PI, proposed idea in the thread in crowdsourcing (Pivot Power), and features provided by crowdsourcing design platform (Quirky.com) are fettered; those actors are not able to obtain what they pursue to

achieve by themselves. Their own road is converged to the crowdsourcing design thread to find the breakthrough to accomplish their objectives. The future of the crowdsourcing design thread is perpetually prosperous by all sorts of participants; the participants search which types of designs are proposed; the features provided by crowdsourcing platform start to be ready to set to calculate and identify the historical information of human participants.

As Figure 3.8 shows, "*the problematization describes a system of alliances, or associations, between entities, thereby defining the identity and what they 'want'.*" [Callon, 1986] In this case, a tentative design group must be formed by problem initiator (PI) and possible participants in order to enhance the proposed idea to be realized.

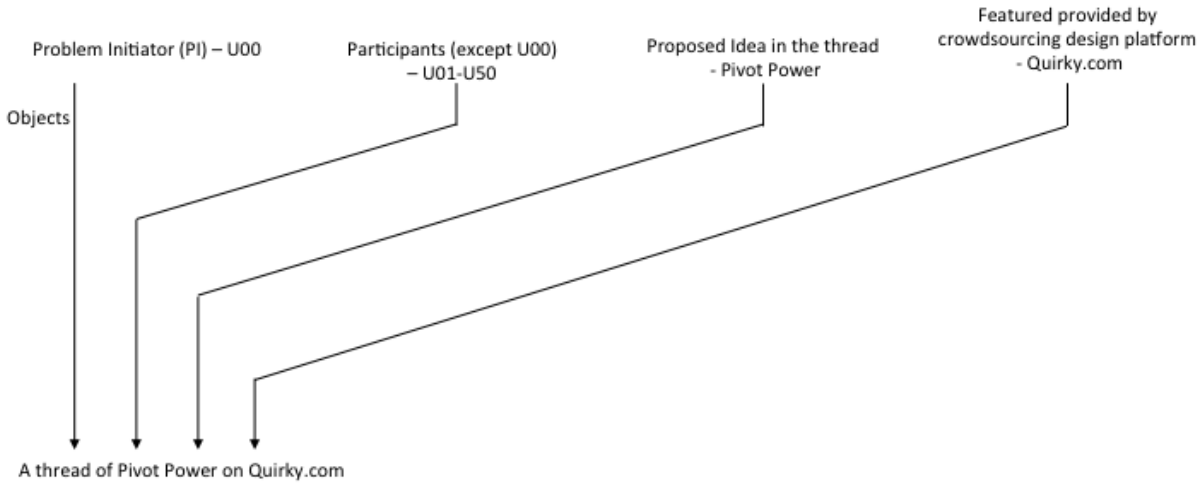

Figure 3.7 Actors and OPP at the problematization in the crowdsourcing design thread, pivot power

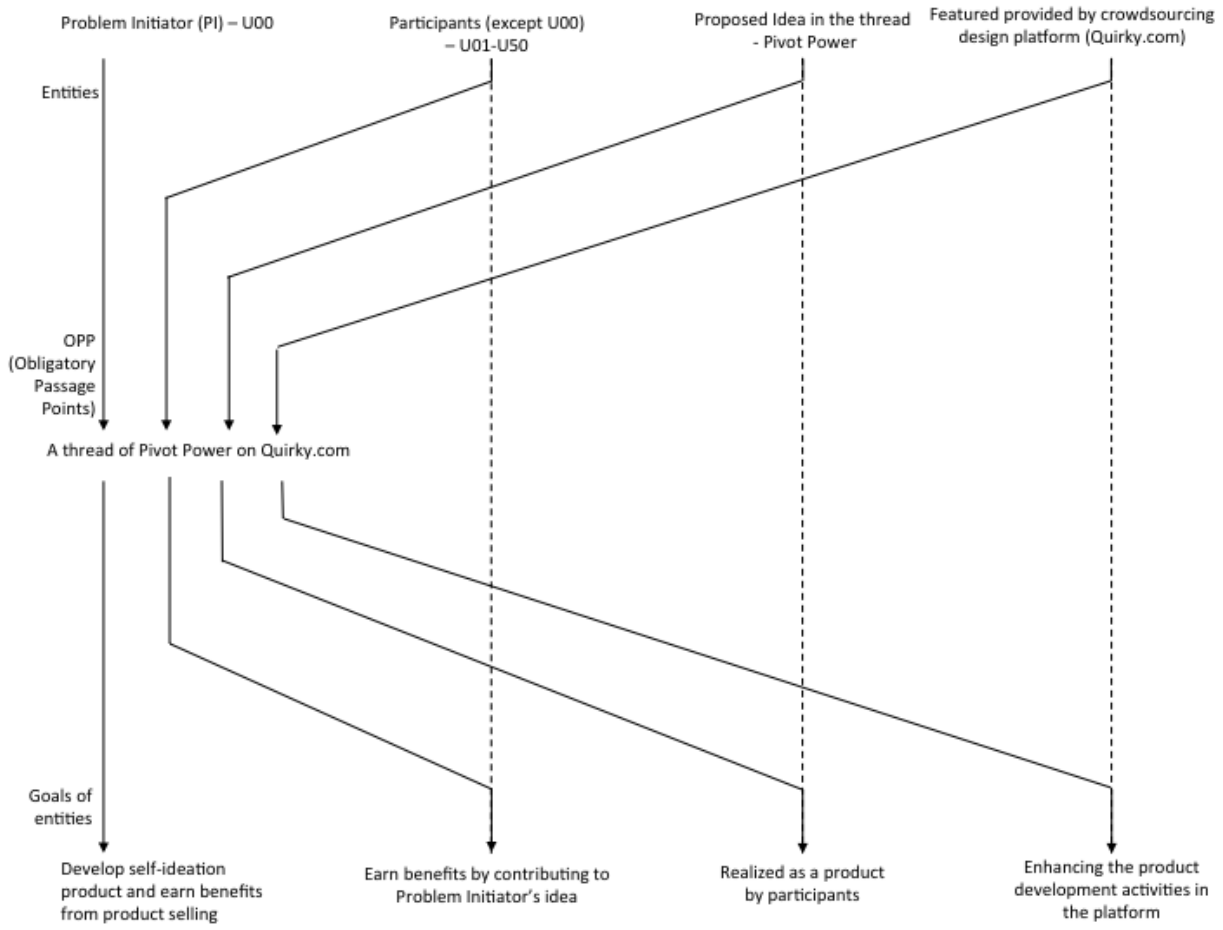

Figure 3.8 Entities and goals at the problematization in the crowdsourcing design thread, pivot power

Interessement

The moment of '*interessement*' is the moment how the allies are locked into place consists of two (sub-) processes. The first one is 'an entity attempts to impose the identity of the other actors.' In crowdsourcing design, activities in the thread by idea generator (or problem initiator) such as replying to participants' comments or referring features which provided by participants. In this design thread, for example, the initiator replied to an actor's comment like this: "… *I've*

never owned the Squid …, but it seems to me that with it, what you gain in outlet count, you lose in organization. … Am I close?"

The second (sub-) process is 'an entity attempts to stabilize the identity of the other actors.' The difference between the first one and the second is that by referring a design feature – the type of outlet – provided by other actors, the initiator keeps trying to attract the actor to be locked into the thread. Such activities by the initiator are that they attempt to impose the other actors into the crowdsourcing design thread. These actions are intended not to lose participants' (other actors) interests to proposed product idea, pivot power. An activity example is that a comment of the initiator to compliment and appreciate the participants who put their own efforts into crowdsourcing design thread, "*Over 40 comments! This is fantastic. Thanks for the great feedback everyone, and please keep it coming!*"

Enrolment

Same as the interessement, the enrolment also has two similar (sub-) processes that define and coordinate the roles – 'an entity finalizes to impose the identity of the other actors' and 'an entity finalizes to stabilize the identity of the other actors.' However, the enrolment happens at the same time when the interessement is completed usually. Callon addressed that "*Enrolment designates the device by which a set of interrelated roles is defined and attributed to actors who accept them. Interessement achieves enrolment if it is successful. To describe enrolment is thus to describe the group of multilateral negotiations, trials of strength and tricks that accompany the interessements and enable them to succeed*" [Callon, 1986].

The enrolment of participants in crowdsourcing design thread – Pivot Power – is achieved by informing the possible benefits to interested participants continuously. Especially, since this enrolment is directly connected to the reputation which the participants will gain in the crowdsourcing design platform, it is important to make them identify their possible benefits clearly. Also, a crowdsourcing design thread seems to be developed independently for a specific product development. However, since other threads can be possible or potential thread for participants in a thread, a thread cannot be fully independent. Idea generator (or problem initiator) is trying to make participants admit their role in the involved thread by keeping emphasis that the proposed idea or product is unique and special for the possibility of success in the market. Also problem initiator provides positive responses or strong agreements on participant's comments. In case of pivot power, finalization for the identity of the other actors happens at the same time with successful interessement.

Activities in the interessement and the enrolment

Multilateral negotiations, trials of strength, and tricks that accompany the interessements and enable them to succeed are the activities in the Interessement and the Enrolment which are occurred by actors. Idea generator (or problem initiator) and other participants communicate to each other to decide which design features are more applicable and helpful for the proposed product idea as negotiations. Trials of strength in crowdsourcing design thread occur or are conducted as that idea generator (or problem initiator) and participants provide evidence to persuade and realize their ideas. For example, in order to avoid patent violation, participants provide similar patent lists or web page links as evidence.

Mobilization

Mobilization consists of two (sub-) processes – 'building consensus among participants and other entities which play roles as representatives' and 'represent the built network to mobilize'. In crowdsourcing design thread, idea generator (or problem initiator) roles a representative if the product idea is developed to a concept design (and eventually a commercial product) successfully. In addition to idea generator, featured information provided by crowdsourcing design platform such as total earnings, number of followers of idea generator (or problem initiator), and promotions in crowdsourcing design platform.

3.5. Conclusion

3.5.1. Summary

This chapter proposes a formalism to represent the translation in Actor Network Theory by applying process and element perspectives in order to fulfill the (sub-) processes of translation. The difference between former research efforts to represent the processes of translation mainly lies in the approach to divide the translation into processes and elements. The former research efforts are usually focused on the actors' behavior to explain as the process only in order to represent it. On the contrary, the proposed method pays attention to an additional view – element perspective which is related to the specific information features. A human actor has its own information features implicitly and uses those features when it behaves in the actor network.

3.5.2. Contribution

The formulation of the translation in ANT for applying into crowdsourcing design environment is the very first step in order to utilize design features which are used in the activities of crowdsourcing design. In a sense, the element perspective proposed in this chapter can be used to identify the flow of design information features. Additionally, the proposed formalism pursues the mathematical approach in order to represent activities in crowdsourcing design thread into the computational type of information. This approach allows the following research methods to extract explicit and implicit design information from crowdsourcing design activities.

CHAPTER 4.

FORMAL DESIGN CONCEPT ANALYSIS FOR CROWDSOURCING DESIGN

4.1. Introduction

In the previous chapter, we have seen that the design features and participants are main entities to understand the activities of entities in crowdsourcing design by retrieving the processes and elements in a real crowdsourcing design thread. By utilizing this perspective, more refined information from the crowdsourcing design activities is possible to be extracted, 'concepts'.

To extract design concepts from crowdsourcing design activities, it is necessary to revisit crowdsourcing design activities. The obstacles of crowdsourcing design activities to be overcome for applying in design domain are summarized as three constraints: (1) limited amount of information called 'scarcity', (2) non-guaranteed quality of contributors and their contributions, and (3) similar contributions by a cluster of unspecified participant group. These constraints provide clues on how to gain and obtain useful information from crowdsourcing design. Therefore, a novel approach to extract useful information or knowledge as a type of concepts including participants' information needs to be developed. As the objective of this research, this chapter provides how the conventional design features are reorganized and how the explicit or implicit concepts are extracted. This chapter consists of the two folds: development of (1) taxonomy for crowdsourcing design and (2) a method for concept extraction including participants' activities.

4.2. Taxonomy of Design Features in Crowdsourcing Design

In developing taxonomy of design features, the conventional design features are researched to set a base. Many researchers have provided design features for product development [Solomon, 1993; Huifen et al., 2003; Brunetti and Golob, 2000; Perks et al., 2005; Li et al., 2004]. Solomon and his colleagues reviewed design features in conceptual design and proposed 'design with physical features'. Those physical features included 'part' information, 'structure', and 'appearance' of product [Solomon, 1993]. The importance of 'function' information related to product design was addressed by Perks and his colleagues [2005]. In addition to this, 'environment' information related to market and technology should be considered in crowdsourcing design. 'Participant' information is also considered to reflect constraints of crowdsourcing design. Detailed explanation and notations of design features of aforementioned categories are explained in following sub-sections. Every design features proposed in this chapter has 0 or 1 value except part name, where 0 and 1 mean that the data or information does not exist and exist in crowdsourcing design thread respectively.

4.2.1. Part and Structure

Usual contributions in crowdsourcing design are provided as comments of participants. When comments include information for enhancing design efforts in the thread, the part name is needed to indicate a specific part. Therefore, the first design feature is the name of part (p_i) (equation (4.1)).

$$P =< p_i > \tag{4.1}$$

, where P is a set of parts which are described in a crowdsourcing design thread and p_i is the exact names of particular parts

In addition to this, the structure information is required to explain the relationship between parts. Mereotopological approach is applied to explain structure after being introduced by Smith [1996] and Varzi [1996]. Mereology means "theory of parts." By Leśniewski [1982], mereology is developed as the name of formal theory of parts and associated concepts. Generally, meanwhile, mereology means a theory of the relationship between part and whole, topology is a theory to describe the relation of the 'is-connected-to' in general. The structures are defined as a type of connection between parts, typically the portion occupied by other parts. Then, the ultimate objective of mereotology theory is to describe the characteristics of regions and the entities, and the relations between regions. Even though the usefulness of mereotopological approach to represent the relations between parts, it is difficult to apply in the crowdsourcing design domain because of the lack of information. Therefore, in this research, topological representation is applied. As a theory of connectivity between parts, the topological approach is more applicable. The best-known topological representation is RCC8, the Region Connection Calculus with eight relationships [Randell and Cohn, 1989; Randell et al., 1992; Cui et al., 1993; Cohn et al., 1997]. Eight mutually exclusive and jointly exhaustive relationships are defined in RCC8: disjoint or disconnected (DC), externally connected or edge coupled (EC), equal (EQ), partially overlapping (PO), tangential proper part (TPP), non-tangential proper part (NTPP), plus two inverse relationships TPPi and NTPPi. In the situation of describing the part relationship without particular part indication in crowdsourcing design, the inverse relationships TPPi and NTPPi are not distinguishable with TPP and NTPP respectively. Therefore, six relationships except TPPi and NTPPi are used in this research, RCC6 in equation (4.2).

$$St = < EQ, EC, DC, PO, TPP, NTPP > \quad (4.2)$$

, where *St* is structure, *EQ* is equal, *EC* is edge coupled, *DC* is disjoint, *PO* is partially overlapping, *TPP* is tangential proper part, and *NTPP* is non-tangential proper part and *EQ*, *EC*, *DC*, *PO*, *TPP*, *NTPP* = {0, 1}

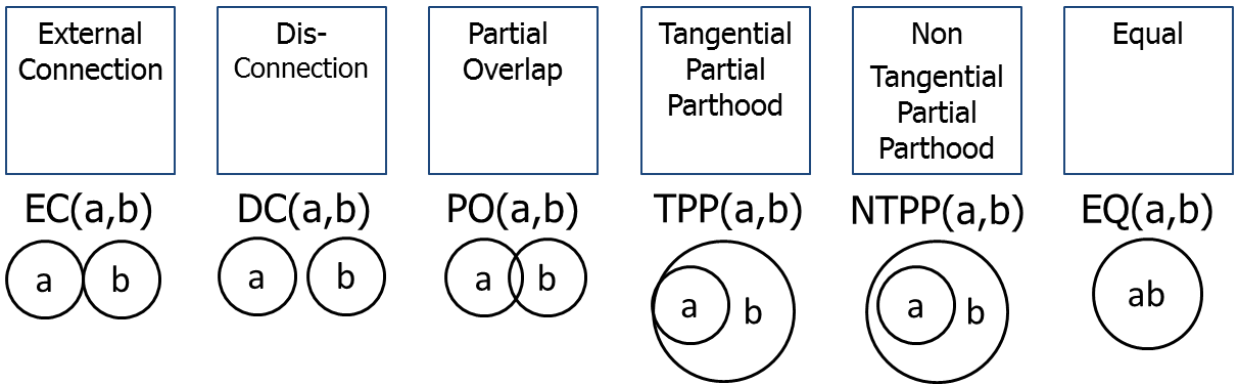

Figure 4.1 RCC6 for crowdsourcing design amended from RCC8

4.2.2. Function

Among various functional definitions, the definition of function from engineering design is often used in this domain. The main perspective in engineering design field argues that function reflects and represents a relation between the input and output of information, energy, and material [Rodenacker, 1971]. The limitation of this definition is that it addresses the systematic behaviors too much, whereas the purposive aspects are usually ignored. Since a system performs multiple functions at the same time, it is too complicated to mention in crowdsourcing design thread. As another perspective, function is defined as "the relation between the goal of a human user and the behavior of a system" [Bobrow, 1984]. Compared to the former definition of Rodenacker's, this emphasizes the purposive aspects while its objective aspects are ignored. In addition to these functional definitions, Rosenman and Gero defined

function as "purpose", a concept which exists in socio-cultural environment [Rosenman and Gero, 1998]. Since function in engineering design bridges the gap between human purposes and objective behaviors of systems, function should consider both perspectives equally [Pahl and Beitz, 1996; Resenman and Gero, 1998; Suh, 2001]. To utilize computational designing of a product, most researchers in intelligent CAD domain have agreed to similar definitions of function with the systematic approach. Umeda et al defined function as "a description of behavior abstracted by human through recognition of the behavior in order to utilize the behavior" [Umeda et al., 1996]. Similarly, Sasajima and his colleagues applied "focus ports and objects" to distinguish functions from other behaviors of systems [Sasajima et al., 1995]. To treat both perspectives, Chen and his colleagues proposed as a comprehensive definition of function with agreement to define functions as the intended behavior of a desired system as "function as an intended transition of the world from a state sensed as unsatisfactory to a desirable one" [Chen et al., 2007].

Representation of Functions in Crowdsourcing Design

In crowdsourcing design, the most applicable type of functions is 'object-focused' function that consists of prohibition-based and transformation-based function, since the comments as the contributing methods are provided as the type of mentioning the uncomfortable features of structure or part which is not provided by existing ones or the type of criticizing other participants' comment and problem statements. Also since the length of comments are not long enough to explain detailed processes or relations for functions, the frequency of providing objectives of specific parts or structure is much higher than other types of functions. Notations

and elements for functions in crowdsourcing design are represented below in equation (4.3) and (4.4).

$$Fn = < O_F, P_F, R_B > \quad (4.3)$$

$$O_F = < T_b, P_b > \quad (4.4)$$

, where $P_F, R_F, T_B, P_B = \{0, 1\}$

4.2.3. Appearance

To describe the (external) appearance of a conceptual design in crowdsourcing environment, the possible design attributes are collected from various research areas from engineering design to marketing [Gershenson and Stauffer, 1999; Johnson et al., 2003; Blijlevens et al., 2009; Balakrishnan and Jacob, 1996]. One of the appearance features discussed by Gershenson and Stauffer was 'surface condition'. Surface condition is the condition of the external surface of products including the color, texture, surface finish, and other surface attributes [Gershenson and Stauffer, 1999]. Those attributes also proposed by Blijlevens and his colleagues [Blijlevens et al., 2009]. Blijlevens et al. highlighted the importance of appearance as a source of consumer perception with design attributes (e.g. color, shape, and texture). Johnson et al. proposed color as one of aesthetic attributes of product [Johnson et al., 2003]. Balakrishnan and Jacob defined product design problem with product attributes with an example of designing a new bar soap. The proposed attributes of product by Balakrishnan and Jacob were the attributes color and shape the specific level of each: for color, blue, green, or white (for color); for shape, oval, round,

rectangular, and spherical (for shape) to employ in the proposed new product [Balakrishnan and Jacob, 1996].

In order to apply the aforementioned attributes, three categories and nine detailed attributes for crowdsourcing design domain: (1) shape - triangle, circle, curve, surface, polygons, (2) color, and (3) size – length, width, and height. Since the limited amount of information and the lack of expertise with regarding to product design of participants, the information about design attributes are collected as exist (one) or non-exist (zero). Equations (4.5) to (4.8) represent the design features of Appearance in crowdsourcing design.

$$Ap = < Sh, Cl, Sz > \quad (4.5)$$

$$Sh = < T_r, C_l, C_r, S_f, P_g > \quad (4.6)$$

,where T_r, C_l, C_r, S_f, P_g={0,1}

$$Cl = \{0, 1\} \quad (4.7)$$

$$Sz = < H, L, W > \quad (4.8)$$

, where *H* is height, *L* is length, and *W* is width; *H*, *L*, *W*={0,1}.

4.2.4. Environment

Design features related to environment are unique information in crowdsourcing design, since the frequency of environmental information being posted are significant. For example, if a posted product idea is similar to existing products in market, participants give feedback with references of existing products or related patent information. When a participant is attracted by the proposed idea, the participant gives feedback with appraisal or a compliment. In this case, the

participant can be a potential customer of the realized product or commercialize the product as well as be a contributor to develop and improve the idea. In this perspective, five features are selected – (1) compliment, (2) competition in market, (3) competition on technology, (4) patent, and (5) intellectual property. In order to make elements of all features to zero or one, 'competition' in market and 'competition' on technologies are divided into high, mid, and low type attributes. Equations (4.9) to (4.11) describe the environmental features in crowdsourcing design.

$$En = < Mkt, Tech > \tag{4.9}$$

, where *Mkt* is market and *Tech* is technology

$$Mkt = < Cpl, Cpt_H, Cpt_M, Cpt_L > \tag{4.10}$$

, where *Cpl* is compliment, Cpt_H is high competition in market, Cpt_M is mid competition in market, and Cpt_L is low competition in market.

$$Tech = < T_H, T_M, T_L, Pt, IP > \tag{4.11}$$

, where $T_H, T_M, T_L$is the level of technology competition is high, mid, low respectively; Pt has 1 when similar patents exist and 0 when similar patents do not exist; and IP has 1 when intellectual property related issues are possible to occur and 0 when those issues are not possible to occur.

4.2.5. Participant

Participants are the basic resources of information or knowledge to prolong the activities in crowdsourcing design. The main constraints of crowdsourcing environment are related to the 'participants'. The anonymity of participants generates non-guaranteed quality of provided

information. Therefore, it is critical to set up attributes to identify and qualify the participants. Actually many crowdsourcing services provide pre-collected and accumulated information about participants. For example, Quirky.com provides detailed participant information, e.g. user id, location, total earning, name, and number of followers, and skills of a participant. In this research, three attributes are selected to identify participants – time, reputation, and task-fitness.

Time

The first parameter is time preference (Υ^{T}). It is used to compare the difference between respondents' time preference and the initiator's time preference after problematization.

To reduce waiting time until a respondent starts to work for an initiator, $g_s(t)$ is important to respondents. Here, $g_s(t)$ is the difference between the time requested by the initiator and the possible start time of the respondent. $g_s(t)$ and $g_s(t)$ are shown in equations (4.13) and (4.14) respectively. As shown in the equations, small or close to zero $g_s(t)$ is the preference of both the respondent and the initiator. $g_e(t)$ is the difference between the expected ending time of the initiator and the possible ending time of the respondent. If $g_e(t) > 0$, a respondent can expect to receive rewards. If $g_e(t) < 0$, a respondent can expect no reward or even a penalty.

$$\Upsilon^{T} = < g_s(t), g_e(t) > \quad (4.12)$$

$$g_s(t) = t_{s(i)} - t_{s(r)} \quad (4.13)$$

$$g_e(t) = t_{e(i)} - t_{e(r)} \quad (4.14)$$

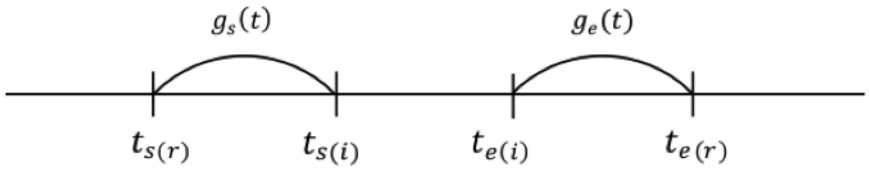

Figure 4.2 Time preference

The following equations (4.15) and (4.16) explain the changes in time preference of the initiator and respondent. Υ_{ir}^{T} is the time preference of the initiator with consideration of the respondent. Υ_{ri}^{T} is the time preference of the respondent with consideration of the initiator. The scale of Υ^{T} is [0, 1]. When $g_s(t)$ is positive and close to zero, Υ_{ir}^{T} and Υ_{ri}^{T} become close to one. When $g_s(t)$ and $g_e(t)$ equal zero, Υ_{ir}^{T} and Υ_{ri}^{T} equal one, since both participants' preferences are fully satisfied. When $g_e(t)$ is greater than zero, Υ_{ir}^{T} becomes close to one and Υ_{ri}^{T} close to zero. A pictorial illustration of these relationships is provided in Figure 4.2.

$$g_s(t)\begin{cases} > 0 \text{ AND } \rightarrow +0, \Upsilon_{ir}^{T} \rightarrow 1 \text{ AND } \Upsilon_{ri}^{T} \rightarrow 1 \\ = 0,\ \Upsilon_{ir}^{T} = 1 \text{ AND } \Upsilon_{ri}^{T} = 1 \\ < 0, \Upsilon_{ir}^{T} = 0 \text{ AND } \Upsilon_{ri}^{T} = 1 \end{cases} \tag{4.15}$$

$$g_e(t)\begin{cases} > 0 \text{ AND } \rightarrow +\infty, \Upsilon_{ri}^{T} \rightarrow 1 \text{ AND } \Upsilon_{ir}^{T} \rightarrow 0 \\ = 0, \Upsilon_{ri}^{T} = 1 \text{ AND } \Upsilon_{ir}^{T} = 1 \\ < 0, \Upsilon_{ri}^{T} \rightarrow 0 \text{ AND } \Upsilon_{ir}^{T} = 1 \end{cases} \tag{4.16}$$

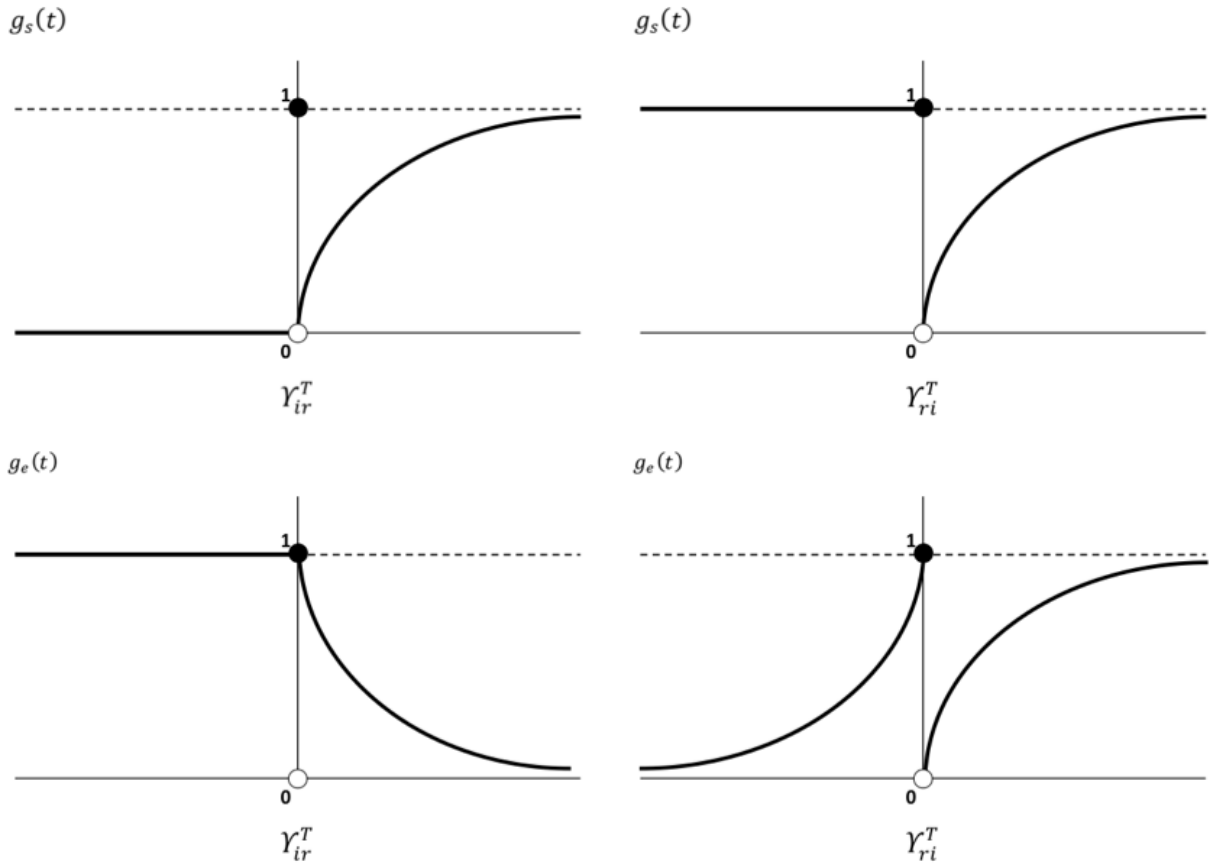

Figure 4.3 Time preference relationships

Reputation

The second parameter is reputation (Υ^R). Reputation in social communities is treated as an important extrinsic motivation of contributors [Lakhani and Wolf, 2005; Huang et al., 2014]. Most current crowdsourcing services provide reputation-related measures from two perspectives: the size of the network and the amount of influence. Usually the network size is denoted by the number of followers and followings. A following is the number of other participants whom

participant i is following. A follower is the number of other participants who follow participant i. Examples can be found in Quirky.com and jovoto.com.

The amount of influence can be measured by various methods. In Quirky.com, for example, participants can earn percentage-like influence value as a reward for their contribution, while in jovoto.com, participants are granted 'karma' based on the amount and quality of their activity. In this study, reputation (Υ^{R}) is defined as shown below.

$$\Upsilon^{R} =< n_i, e_i > \quad (4.17)$$

, where $n_i = \frac{\text{Number of Followers}}{\text{Number of Followers+Number of Followings}}$, $n_i \in Z^{[0,1]}$ and $e_i = \text{normalized total earnings}$, $i_i \in Z^{[0,1]}$

Network Size: The first measure, n_i for reputation, Υ^{R} is the ratio of the number of followers to the entire network of an participant *i*. Figure 4.4 illustrates three different patterns of the measure n_i. In case (1), the number of followers of participant *i* increased rapidly (probably by generating significant ideas or contributions in the early days). However, increasing the number of followers has decreased the ratio due to the lack of impressive contributions. On the other hand, in case (3), participant i's contributions are not significant in the early days, but participant *i* provides later significant contributions to other participants. In case (2), the graph has a constant slope, which means that the evaluation of participant i's contribution is continuously positive.

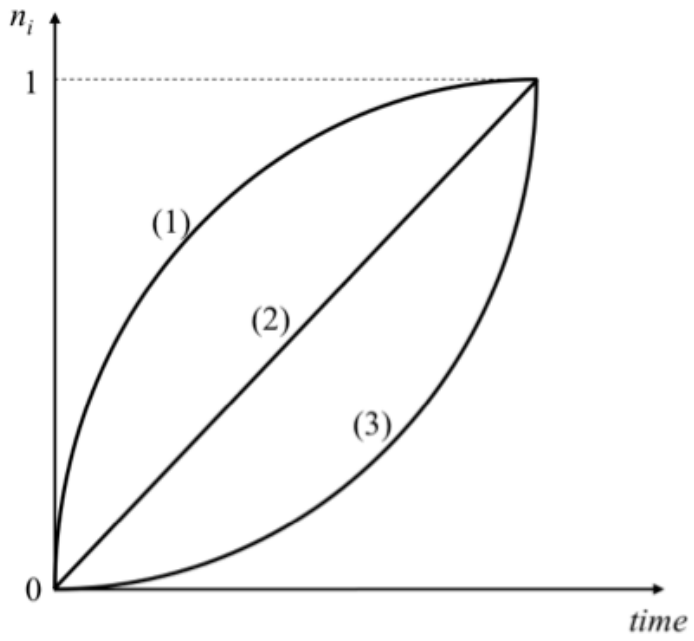

Figure 4.4 Three different patterns of n_i

***Total Earning*:** The second measure for reputation, Υ^R, is total earnings, e_i, which is the min-max normalized value of total earnings of participant *i*. Using the min-max normalization method, e_i is the relative value of total earnings to those of other participants. In this case, e_i of the highest-earning participant equals one. If the normalized total earnings of a participant are close to one, it means that the participant receives relatively higher earnings than other participants. In addition, the participant will enjoy a better reputation. From a time series perspective, changes in e_i must also be considered. If the trend is toward an increase in e_i, the participant's current efforts increase significantly and the reputation of the participant improves. In contrast, a decreasing trend in e_i means that the current reputation of the participant has taken a turn for the worse.

Task-fitness (based on Expertise)

The third parameter is task fitness (Υ^F). Task fitness consists of two measures: categories and types of contributions. Although participants expect their contributions to be accepted by the initiator, this is a probabilistic expectation. To increase the probability of acceptance, contributing participants must find better-fit projects for themselves. In order to describe this search process, we introduce the concept of task fitness. To confirm the task fitness of a project, two subsidiary measures are proposed: the importance of the category (c_i) and the methods of contribution to other participants' ideas and posts (m_i). Similar measures are used by various crowdsourcing services such as Quirky.com, jovoto.com, and openIDEO. Here we explain these two measures with the case of Quirky.com. In Quirky.com, the contribution of a participant is categorized into eight domains: electronics and power, health and fitness, home and garden, kitchen, parenting, play, travel and adventure, and wild card. Quirky.com also has eight methods by which participants can contribute, including ideas, research, design, enhancement, style, naming, tagline, and pricing.

$$\Upsilon^F = < c_i, m_i > \quad (4.18)$$

Category: The first measure to propose for task fitness is the ratio of category expertise (c_i). In order to identify participant i's category expertise, the desired amount of expertise for each category (c_i^k) must be identified in advance. For this study, we calculate the participants' category expertise based on the ratio of the idea and project contributions in a certain category to the total number of contributed ideas and projects.

$$c_i = \{\frac{c_i^1}{\sum_1^n c_i^k}, \frac{c_i^2}{\sum_1^n c_i^k}, \dots, \frac{c_i^n}{\sum_1^n c_i^k}\} \quad (4.19)$$

For example, as shown in Table 4.1, if participant 1 generates four ideas for electronics and power (category 1), one for kitchen, one for play, and two for wild card, participant 1's expertise in these categories is calculated with the equation pertaining to c_i. Participant 1 is found to have the greatest expertise in the electronics and power category. Participant 2, on the other hand, has the greatest expertise in the kitchen category. This measure can be used when an initiator finds better-fit participants who have the desired expertise in specific categories.

Table 4.1 Sample participants' contributions by category

Category	1 Electronics & Power	2 Health Fitness	3 &Home & Garden	4 Kitchen	5 Parenting	6 Play	7 Travel & Adventure	8 Wild Card	Total
Participant 1	4	0	0	1	0	1	0	2	8
	0.5	0	0	0.125	0	0.125	0	0.25	1
Participant 2	3	1	1	7	2	0	0	0	14
	0.2143	0.0714	0.0714	0.5000	0.1429	0	0	0	1
…	…	…	…	…	…	…	…	…	…

***(Contributing) Method*:** As shown on Table 4.2 below, the second measure of task fitness is the average influence achieved using a certain method (m_i). m_i is a set of elements reflecting the averaged influence earned from each method of contribution.

Table 4.2 Calculation of m_i

Participant *i*	Method (*p*)

		1	2	3	…	m
Idea (q)	1	m_{11}	m_{21}	m_{31}	…	m_{m1}
	2	m_{12}				…
	3	m_{13}		…		…
	…	…				…
	n	m_{1n}	…	…	…	m_{mn}
	SUM	$\sum_{q=1}^{n} m_{1q}$	$\sum_{q=1}^{n} m_{2q}$	…	…	$\sum_{q=1}^{n} m_{nq}$
	AVG	$\frac{\sum_{q=1}^{n} m_{1q}}{n}$	$\frac{\sum_{q=1}^{n} m_{2q}}{n}$	…	…	$\frac{\sum_{q=1}^{n} m_{2q}}{n}$

$$m_i = \left\{\frac{\sum_{q=1}^{n} m_{1q}}{n}, \frac{\sum_{q=1}^{n} m_{2q}}{n}, \dots, \frac{\sum_{q=1}^{n} m_{2q}}{n}\right\} \quad (4.20)$$

For example, if participant *i* influences 18 ideas and earns recognition from the idea initiators, m_i is calculated as shown in Table 4.3. In this case, participant *i* has the strongest influence on the initial idea and the name. On the other hand, participant i has no input in terms of style and sales.

Table 4.3 Sample case for m_i calculation (data collected from Quirky.com)

Influencing Project (Title)	Idea	Research	Design	Style	Name	Tagline	Price	Sales
Confort	0.176462	0.011261	0	0	0	0	0	0
Boil Buoy	0.084746	0	0	0	0.033333	0	0	0
Cable Collar	0.127652	0	0	0	0	0	0	0
Shower Station	0.052083	0.017454	0	0	0	0	0	0
Trek Support Backpack	0	0	0.010204	0	0.021739	0	0	0
Trek Support	0	0	0.010204	0	0.021739	0	0	0

Messenger								
Trek Support iPad Case	0	0	0.010204	0	0.021739	0	0	0
Trek Support Tote	0	0	0.010204	0	0.021739	0	0	0
Contour	0	0.012853	0	0	0	0	0	0
Sure Scoop	0	0.011364	0	0	0	0	0	0
Splash Stacks	0	0	0	0	0	0	0.008525	0
Pin Point	0	0	0	0	0	0	0.008525	0
Grid	0	0	0	0	0	0	0.008244	0
Total Influenced	0.440943	0.052932	0.040816	0	0.120289	0	0.025294	0
Average Influence earned ($\boldsymbol{m_i}$)	0.033919	0.0040717	0.003140	0	0.009253	0	0.001946	0

4.2.6. Taxonomy of Design features

Taxonomy of design features discussed from section 4.2.1 to 4.2.5 for describing for crowdsourcing design is shown in Figure 4.5. Part, sturcture, and appearance are categorized as physical features and function is categorized as non-physical feature. Those four features are related to internal factors of product, while features in 'environment' are related to external product factors. A forementioned five design feature groups are related product design, while features of participant are solely related designer (or contributor) of products.

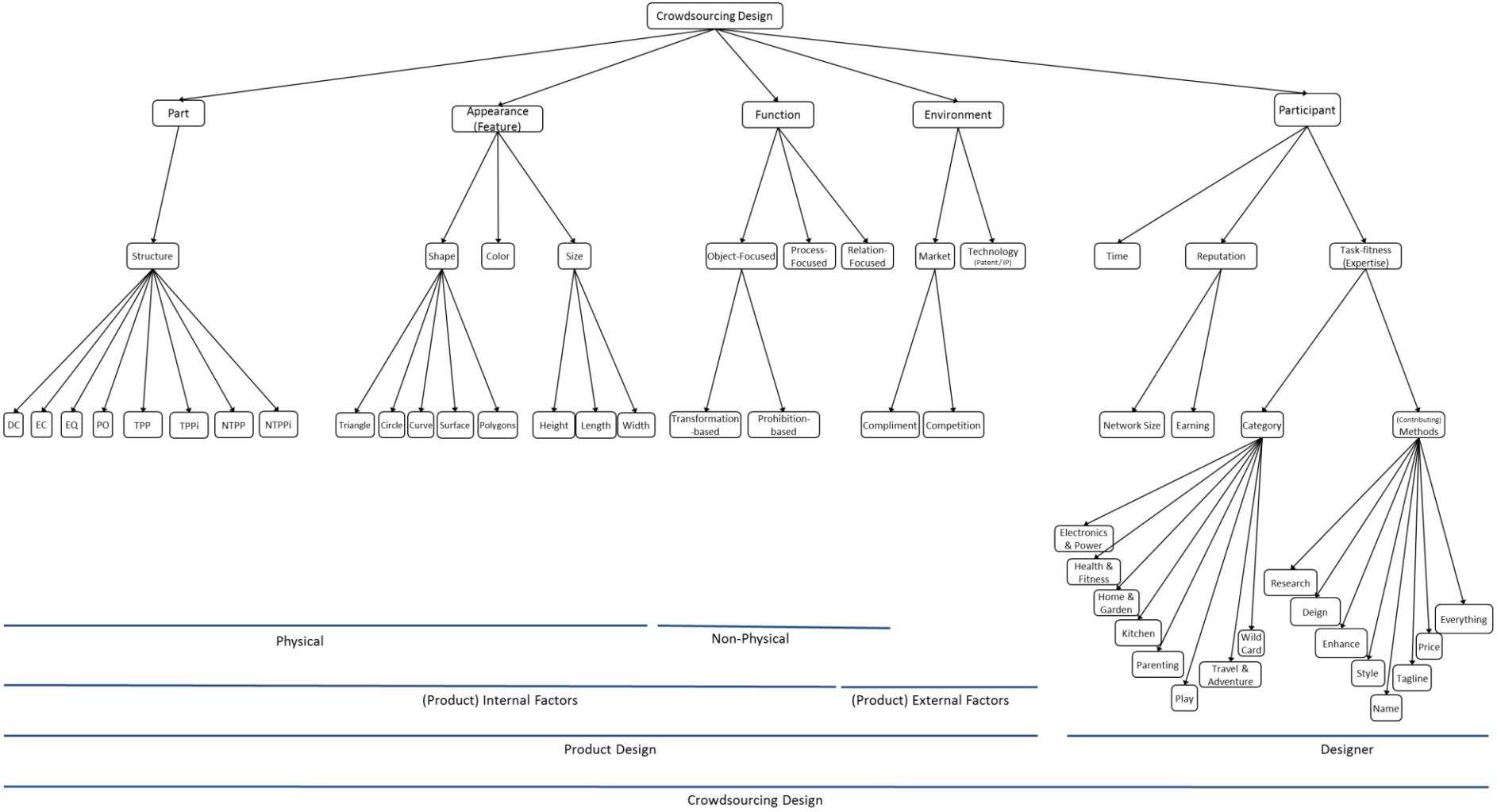

Figure 4.5 Taxonomy of design features in crowdsourcing design

4.3. Formal Concept Analysis

Formal concept analysis [Ganter and Wille, 1999, Carpineto and Romano, 2004] is a data analysis method based on a mathematical model as 'Galois lattices' or 'concept lattices'. It provides mathematical solutions to problems in the domain of data analysis and knowledge process. In this paper, we introduce basic concepts and related definitions.

Formal context [Ganter and Wille, 1999]

Formal context K=(G, M, I) consists of a set of objects (G), a set of attributes (M), and binary relations between G and M ($I \subseteq G \times M$). That is, the elements of G and M represent the relevant objects and its attributes respectively. In addition, when an object, g, has an attribute, m, it represents as *gIm* or $(g, m) \in I$ and means *g* has *m*. ■ (Definition 1)

Formal context as a basic structure of formal concept analysis can be represented as a data table. The heads of row and column of the data table consist of objects and attributes that compose formal contexts. Each cell of the data table is marked 'x' when the relevant object and attribute has a binary relation and otherwise is left 'blank'. Table 4.4 is an example of formal context which is represented contributed design information by users with representation of participants U00~ U50 as objects G and design information in crowdsourcing design as attributes M. For the purpose of describing the theoretical concepts, the descriptive information below are partially selected from original case.

Table 4.4 Example of formal context about crowdsourcing activities

Participant ID	S1	S2	S3	S4	S5	S6	F1	F2	F3	A1	A2	A3	E1	E2
U00	1	1		1	1	1	1		1			1	1	
U01														
U02														
U03									1					
U04													1	
U05													1	
U06							1					1	1	
U07	1						1							
U08										1				
U09					1		1							
U10	1			1		1	1		1			1	1	1
U11							1					1		
U12						1	1			1		1		
U13							1				1			
U14							1						1	
U15							1						1	
U16														
U17						1			1	1		1		
U18														
U19							1			1		1		
U20													1	
U21														
U22										1			1	
U23							1					1	1	
U24							1							
U25													1	
U26														
U27														1
U28	1									1		1		1
U29													1	
U30														

Concepts as basic units of information can be extracted by clustering objects that have the same attributes from the formal context. Each concept is defined as a pair, (O, A) and its formal definition is provided below.

Formal concept [Ganter and Wille, 1999]

For formal context K=(G, M, I), when an arbitrary formal concept (O, A) as O⊆G, A⊆M satisfies intent(O)=A ∧ extent(A)=O.

when intent(O):={a∈M|∀o∈O:(o, a) ∈I}=O’, extent(A):={o∈G|∀a∈A:(o, a) ∈I}=A’. ■

(Definition 2)

For arbitrary objects O⊆G, intent(O) is a set that consists of attributes which are commonly shared with all objects in O. Extracted concepts from formal context are able to define super- and sub-concept relation based on extent or intent.

Table 4.5 Extracted concepts from formal concept on Table 4.4

ConceptID	Extent	Intent
c(0)	{U00; U01; U02; U03; U04; U05; U06; U07; U08; U09; U10; U11; U12; U13; U14; U15; U16; U17; U18; U19; U20; U21; U22; U23; U24; U25; U26; U27; U28; U29; U30}	{}
c(1)	{U10; U27; U28}	{P14}
c(2)	{U00; U04; U05; U06; U10; U14; U15; U20; U22; U23; U25; U29}	{P13}
c(3)	{U00; U06; U10; U11; U12; U17; U19; U23; U28}	{P12}
c(4)	{U08; U12; U17; U19; U22; U28}	{P10}
c(5)	{U22}	{P10; P13}
c(6)	{U12; U17; U19; U28}	{P10; P12}
c(7)	{U00; U03; U10; U17}	{P9}
c(8)	{U00; U06; U07; U09; U10; U11; U12; U13; U14; U15; U19; U23; U24}	{P7}
c(9)	{U00; U06; U10; U14; U15; U23}	{P7; P13}
c(10)	{U00; U06; U10; U11; U12; U19; U23}	{P7; P12}
c(11)	{U00; U06; U10; U23}	{P7; P12; P13}
c(12)	{U13}	{P7; P11}
c(13)	{U12; U19}	{P7; P10; P12}
c(14)	{U00; U10; U12; U17}	{P6; P12}
c(15)	{U12; U17}	{P6; P10; P12}
c(16)	{U00; U10; U17}	{P6; P9; P12}
c(17)	{U17}	{P6; P9; P10; P12}
c(18)	{U00; U10; U12}	{P6; P7; P12}

c(19)	{U12}	{P6; P7; P10; P12}
c(20)	{U00; U09}	{P5; P7}
c(21)	{U00; U07; U10; U28}	{P1}
c(22)	{U00; U10; U28}	{P1; P12}
c(23)	{U10; U28}	{P1; P12; P14}
c(24)	{U28}	{P1; P10; P12; P14}
c(25)	{U00; U07; U10}	{P1; P7}
c(26)	{U00; U10}	{P1; P4; P6; P7; P9; P12; P13}
c(27)	{U10}	{P1; P4; P6; P7; P9; P12; P13; P14}
c(28)	{U00}	{P1; P2; P4; P5; P6; P7; P9; P12; P13}
c(29)	{}	{P1; P2; P3; P4; P5; P6; P7; P8; P9; P10; P11; P12; P13; P14}

Superconcept-Subconcept Relation [Ganter and Wille, 1999]

For given arbitrary concepts (O1, A1), (O2, A2)∈B(K), superconcept-subconcept relation (O1, A1)≤(O2, A2) as a partial order relation is defined as below.

(O1, A1)≤(O2, A2) ⇔ O1⊆O2(⇔ A1⊇A2). ■ (Definition 3)

Lower Neighbor and Upper Neighbor [Ganter and Wille, 1999]

B(K) is a set of every concepts in formal context K=(G, M, I). For arbitrary concepts (X1, Y1) and (X2, Y2)∈B(K), (X1, Y1) is a lower neighbor of (X2, Y2) when a concept (X3, Y3) does not exist which satisfies (X1, Y1)<(X2, Y2) and (X1, Y1)<(X3, Y3)<(X2, Y2) in B(K) and (X2, Y2) is a upper neighbor of (X1, Y1). It is represented as (X1, Y1)≺(X2, Y2). ■ (Definition 4)

Every super- and sub-concept relations among all the concepts in formal context K=(G, M, I) are partial order relations. Hierarchical concept structure generated by super- and sub-concept relations between concepts is called as 'Galois Lattices' (or Concept Lattices and represented as L:=(B(K), $E_{\leq}$). Extracted concepts and super- and sub-relation between those concepts from formal context in Table 4.4. can be visualize using Hasse Diagram as Figure 4.6.

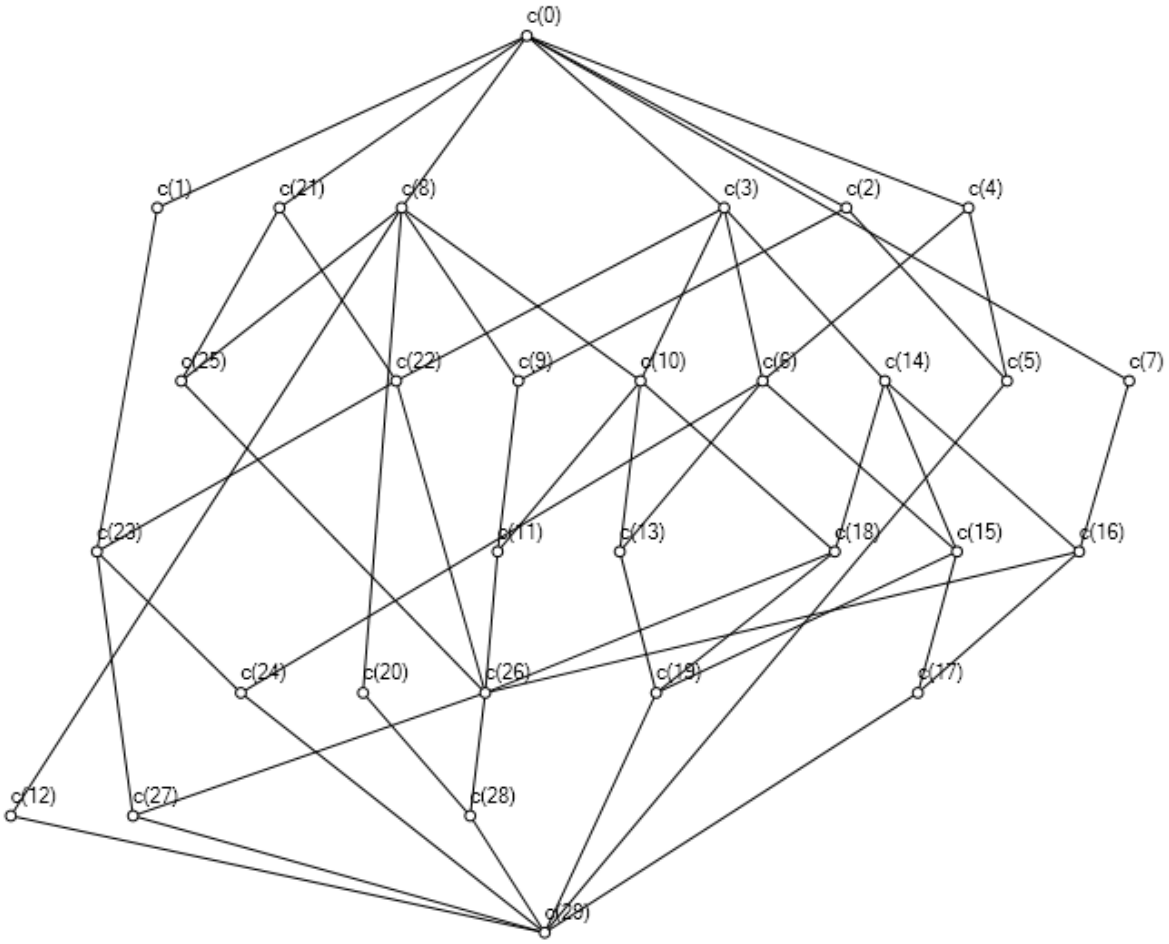

Figure 4.6 Galois lattices of formal concepts in Table 4.5

Implication [Carpineto and Romano, 2004]

When two arbitrary attributes Q, R⊆M in the given formal context K=(G, M, I) satisfy extent(Q) ⊆ extent(R), it is defined as 'Q imply R' and descripted, Q⇒R. ■ (Definition 5)

For arbitrary Q, R ⊆ M, objects which have attributes Q and attributes R can be generated by extent(Q) and extent(R) respectively.

Association Rule [Carpineto and Romano, 2004]

When two arbitrary attributes Q, R⊆M in the given formal context K=(G, M, I) satisfy $\sup(Q \rightarrow R) = \frac{|\text{extent}(Q \cup R)|}{|G|} \geq minsup$ and $\text{conf}(Q \rightarrow R) = \frac{|\text{extent}(Q \cup R)|}{|\text{extent}(Q)|} \geq minconf$, 'Q is associated with R'. It is descripted as $Q \rightarrow R_{minsup,minconf}$, where *minsup* ∈ [0, 1] and *minconf* ∈ [0, 1]. ■

(Definition 6)

$\frac{|\text{extent}(Q \cup R)|}{|G|}$ and $\frac{|\text{extent}(Q \cup R)|}{|\text{extent}(Q)|}$ mentioned in [Definition 6] are called 'support' and 'confidence' of association $Q \rightarrow R$ respectively. The support is the probability of an object containing both Q and R. The confidence is the conditional probability that an object contains R, given that it contains Q. Especially, the parameters *minsup* (minimum support) and *minconf* (minimum confidence) are user-supplied thresholds, for the required minimum support and minimum confidence. In other words, the paramenter *minsup* is the minimum threshold to determine whether an association rule exists between Q and R based on how many attributes are valid at least between Q and R. The parameter *minconf* is the minimum threshold to determine whether an association rule exists between Q and R based on how many objects, which have attributes Q

have, also attributes R at least. Implication is a special case of association rules, because an association rule when minsup=0 and minconf=1 is the same relation of implication.

In order to mingle the aforementioned definitions with participant information in crowdsourcing design, evaluation about the activities of participants needs to be conducted.

Participant Group Score (PGS)

Based on the activities in a whole crowdsourcing design platform, participant can be evaluated. Also, in order to identify the value of a generated concept from crowdsourcing design activity, user group value should be calculated. Value of each user is calculated based on the level of time, reputation, and task-fitness as discussed in the previous section. For representation purpose, time, Υ^T, is calculated based on the difference between the time of problem statement posted and the time of comment posted. If a user input multiple comments, level of time is calculated as an averaged one. Reputation, Υ^R, is calculated based on total earning and follower size, level of reputation is calculated. Task-fitness, Υ^F, is generated from activities from the participant's activities related to categories and methods which participants contributed to design projects. After calculating each measure, then normalize those scores as 0 to 1 scale respectively. Then average those scores to set as individual participant score, PIS_i. Lastly, for gaining participant group score ($PGS_{c(j)}$) for concept j, conduct product sum of each PIS_i value in a concept.

4.4. Case Study

To illustrate and apply the proposed method in the previous section, the case study is conducted with a crowdsourcing design project, Pivot Power, in Quirky.com. The details of Pivot Power development are described in section 3.4.1.

4.4.1. Build a Formal Context table using Pivot Power.

To build a formal context table for Pivot Power, 43 design features are extracted: 16 specified parts with names, 6 part-structure relations, 5 function types, 9 product appearance related features, and 7 environment related features. The total number of distinguished participants including idea generator (or problem initiator) is 51. To mark each cell of the blank table with 'x', every comment on pivot power thread were investigated to determine whether a binary relationship between the relevant participant and design features existed or not. If design features were mentioned by participants, 'x' marked in relevant cells. For example, if participant 10 (U10) put a comment, 'My guess is that the ***patent*** was not for a modular design strictly speaking, but for the cool ***push button to extract the plug***', U10 had relations with design features – patent and object-focused function. In the same way, all the relationships between participants and design features are extracted. As the result of investigation, a 51 x 43 matrix as formal context for Pivot Power was built. Formal context for Pivot Power is shown at Table 4.6.

Table 4.6 Formal context of Pivot Power

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	S1	S2	S3	S4	S5	S6	S7	S8	F1	F2	F3	F4	F5	A11	A12	A13	A14	A15	A2	A31	A32	A33	E11	E12	E122	E123	E211	E212	E213
U00	1	1	1	1	1	1	1	1									1	1		1	1		1		1	1	1		1		1					1	1	1				1			
U01																																													
U02																																						1						
U03							1																						1															
U04																																						1						
U05																																						1						
U06		1																							1		1									1		1						
U07		1						1									1								1	1	1																	
U08																																	1												
U09																					1				1	1																			
U10		1								1	1	1	1					1		1			1		1	1	1		1								1						1		1
U11																									1	1											1							
U12			1				1																1		1	1						1			1	1	1						
U13			1																						1	1								1										
U14							1																		1	1												1						
U15							1																		1		1											1						
U16																																						1						
U17										1													1						1					1				1						
U18		1																																											
U19																									1	1							1					1						
U20																																						1						
U21																																												
U22																															1											1		
U23							1																		1		1									1	1	1	1				
U24			1																						1	1																		
U25																																						1						
U26																																						1						
U27																																											1		
U28										1				1			1												1	1		1	1		1	1	1			1	1		1		
U29																																								1					
U30																1																													
U31																																						1	1					
U32	1																								1	1					1									1				
U33																																						1						
U34															1										1	1			1															
U35			1				1										1								1	1												1						
U36					1		1			1													1		1	1		1																
U37																																						1						
U38																																						1						
U39		1	1														1								1	1										1	1	1						
U40			1			1																	1		1	1																	
U41																																													
U42																																						1						
U43																																													

U44																																1						1						
U45																																												
U46									1														1		1									1									
U47														1							1		1	1													1						
U48																																						1						
U49	1																							1	1																				
U50							1																	1	1										1										

4.4.2. Formal concepts from built formal context

With applying the proposed method and already built formal context, total 109 formal concepts are generated. Table 4.7. shows whole list of concepts generated from Table 4.6. In order to interpret the extracted concepts, an example is provided with concept 102 below.

Table 4.7 Extracted concepts from Formal Context of Power Pivot

ConceptID	Extent	Intent
c(102)	{U10}	{P2; P10; P11; P12; P13; S2; S4; S7; F1; F2; F3; F5; A31; E211; E213}
c(89)	{U00; U40}	{P3; P6; S7; F1; F2}
c(78)	{U36}	{P6; P7; P10; S7; F1; F2; F4}
c(33)	{U12; U19}	{F1; F2; A14; A33}
c(14)	{U00; U22}	{A12; E123}
c(108)	{U00}	{P1; P2; P3; P4; P5; P6; P7; P8; S1; S2; S4; S5; S7; F1; F2; F3; F5; A12; A31; A32; A33; E123}
c(70)	{U14; U35}	{P7; F1; F2; E11}
c(98)	{U00; U07; U10}	{P2; F1; F2; F3}
c(87)	{U00; U35}	{P3; P7; S1; F1; F2}
c(54)	{U10; U46}	{P10; F1; F3; A31}
c(61)	{U00; U03}	{P7; F5}
c(38)	{U00; U17}	{S7; F5; A33}
c(58)	{U10; U36}	{P10; S7; F1; F2}
c(51)	{U10; U28}	{P10; A31; E211}
c(74)	{U00; U34}	{P6; F1; F2; F5}
c(85)	{U00; U12}	{P3; P7; S7; F1; F2; A31; A32; A33}
c(67)	{U00; U23}	{P7; F1; F3; A31; A32; A33}
c(107)	{U32}	{P1; F1; F2; A12; E12}
c(1)	{U10; U27; U28}	{E211}
c(72)	{U00; U12; U36}	{P7; S7; F1; F2}

c(41)	{U00; U09}	{S5; F1; F2}
c(34)	{U00; U10; U34}	{F1; F2; F5}
c(92)	{U00; U06; U39}	{P2; F1; A32}
c(83)	{U00; U35; U39}	{P3; S1; F1; F2}
c(99)	{U00; U10}	{P2; S2; S4; S7; F1; F2; F3; F5; A31}
c(40)	{U00; U10; U12}	{S7; F1; F2; A31}
c(100)	{U00; U07; U39}	{P2; S1; F1; F2}
c(25)	{U00; U06; U23}	{F1; F3; A32}
c(63)	{U14; U15; U23; U35}	{P7; F1; E11}
c(37)	{U00; U10; U17}	{S7; F5}
c(45)	{U00; U07; U35; U39}	{S1; F1; F2}
c(8)	{U00; U12; U23; U28; U39}	{A31; A32; A33}
c(32)	{U13; U50}	{F1; F2; A2}
c(84)	{U00; U12; U35}	{P3; P7; F1; F2}
c(101)	{U00; U07}	{P2; S1; F1; F2; F3}
c(22)	{U00; U12; U23; U39}	{F1; A31; A32; A33}
c(31)	{U00; U10; U12; U39}	{F1; F2; A31}
c(12)	{U12; U28}	{A14; A31; A32; A33}
c(21)	{U00; U10; U12; U23; U39; U46}	{F1; A31}
c(106)	{U00; U32}	{P1; F1; F2; A12}
c(105)	{U00; U32; U49}	{P1; F1; F2}
c(42)	{U00; U07; U28; U35; U39}	{S1}
c(43)	{U00; U28; U39}	{S1; A31; A32; A33}
c(64)	{U00; U12; U23}	{P7; F1; A31; A32; A33}
c(73)	{U00; U34; U36; U40}	{P6; F1; F2}
c(50)	{U10; U28; U46}	{P10; A31}
c(52)	{U17; U28}	{P10; A15; A33}
c(96)	{U00; U07; U10; U39}	{P2; F1; F2}
c(94)	{U00; U06}	{P2; F1; F3; A32}
c(49)	{U10; U17; U28; U36; U46}	{P10}

c(18)	{U06; U14; U15; U23; U35; U47}	{F1; E11}
c(24)	{U06; U15; U23}	{F1; F3; E11}
c(39)	{U00; U10; U12; U36; U40; U47}	{S7; F1; F2}
c(46)	{U30}	{P16}
c(2)	{U28; U29; U31; U32}	{E12}
c(30)	{U00; U11; U12; U19; U39}	{F1; F2; A33}
c(16)	{U00; U03; U10; U17; U34}	{F5}
c(91)	{U00; U06; U07; U10; U39}	{P2; F1}
c(11)	{U12; U19; U28}	{A14; A33}
c(7)	{U00; U10; U12; U23; U28; U39; U46}	{A31}
c(36)	{U00; U12; U17}	{S7; A33}
c(65)	{U00; U15; U23}	{P7; F1; F3}
c(13)	{U00; U22; U28; U32}	{A12}
c(62)	{U00; U12; U14; U15; U23; U35; U36; U50}	{P7; F1}
c(9)	{U08; U12; U19; U28; U44}	{A14}
c(76)	{U34}	{P6; P15; F1; F2; F5}
c(56)	{U10; U17}	{P10; S7; F5}
c(27)	{U00; U10; U23; U46}	{F1; F3; A31}
c(15)	{U28; U32}	{A12; E12}
c(104)	{U00; U39}	{P2; P3; S1; F1; F2; A31; A32; A33}
c(26)	{U06; U23}	{F1; F3; A32; E11}
c(5)	{U00; U11; U12; U17; U19; U23; U28; U39}	{A33}
c(86)	{U12}	{P3; P7; S7; F1; F2; A14; A31; A32; A33}
c(60)	{U00; U03; U12; U14; U15; U23; U35; U36; U50}	{P7}
c(19)	{U00; U11; U12; U19; U23; U39}	{F1; A33}
c(97)	{U00; U10; U39}	{P2; F1; F2; A31}
c(55)	{U10; U17; U36}	{P10; S7}
c(57)	{U17}	{P10; S7; F5; A15; A33}
c(44)	{U00; U28}	{S1; A12; A31; A32; A33}
c(81)	{U13}	{P3; F1; F2; A2}

c(77)	{U00; U36}	{P6; P7; S7; F1; F2}
c(10)	{U44}	{A14; E11}
c(95)	{U06}	{P2; F1; F3; A32; E11}
c(88)	{U35}	{P3; P7; S1; F1; F2; E11}
c(68)	{U23}	{P7; F1; F3; A31; A32; A33; E11}
c(103)	{U07}	{P2; P9; S1; F1; F2; F3}
c(47)	{U34; U47}	{P15; F1; F2}
c(71)	{U50}	{P7; F1; F2; A2}
c(90)	{U00; U06; U07; U10; U18; U39}	{P2}
c(69)	{U00; U12; U14; U35; U36; U50}	{P7; F1; F2}
c(23)	{U00; U06; U07; U10; U15; U23; U46}	{F1; F3}
c(79)	{U00; U12; U13; U24; U35; U39; U40}	{P3; F1; F2}
c(3)	{U02; U04; U05; U06; U14; U15; U16; U20; U23; U25; U26; U31; U33; U35; U37; U38; U42; U44; U47; U48}	{E11}
c(35)	{U00; U10; U12; U17; U36; U40; U47}	{S7}
c(17)	{U00; U06; U07; U09; U10; U11; U12; U13; U14; U15; U19; U23; U24; U32; U34; U35; U36; U39; U40; U46; U47; U49; U50}	{F1}
c(0)	{U00; U01; U02; U03; U04; U05; U06; U07; U08; U09; U10; U11; U12; U13; U14; U15; U16; U17; U18; U19; U20; U21; U22; U23; U24; U25; U26; U27; U28; U29; U30; U31; U32; U33; U34; U35; U36; U37; U38; U39; U40; U41; U42; U43; U44; U45; U46; U47; U48; U49; U50}	{}
c(93)	{U00; U06; U07; U10}	{P2; F1; F3}
c(20)	{U00; U06; U12; U23; U39}	{F1; A32}
c(28)	{U00; U07; U09; U10; U11; U12; U13; U14; U19; U24; U32; U34; U35; U36; U39; U40; U47; U49; U50}	{F1; F2}

c(6)	{U00; U06; U12; U23; U28; U39}	{A32}
c(75)	{U00; U36; U40}	{P6; S7; F1; F2}
c(82)	{U00; U12; U40}	{P3; S7; F1; F2}
c(53)	{U10; U36; U46}	{P10; F1}
c(80)	{U00; U12; U39}	{P3; F1; F2; A31; A32; A33}
c(29)	{U14; U35; U47}	{F1; F2; E11}
c(66)	{U15; U23}	{P7; F1; F3; E11}
c(48)	{U47}	{P15; S7; F1; F2; E11}
c(4)	{U31}	{E11; E12}
c(59)	{U28}	{P10; P14; S1; A11; A12; A14; A15; A31; A32; A33; E12; E122; E211}
c(109)	{}	{P1; P2; P3; P4; P5; P6; P7; P8; P9; P10; P11; P12; P13; P14; P15; P16; S1; S2; S3; S4; S5; S6; S7; S8; F1; F2; F3; F4; F5; A11; A12; A13; A14; A15; A2; A31; A32; A33; E11; E12; E122; E123; E211; E212; E213}

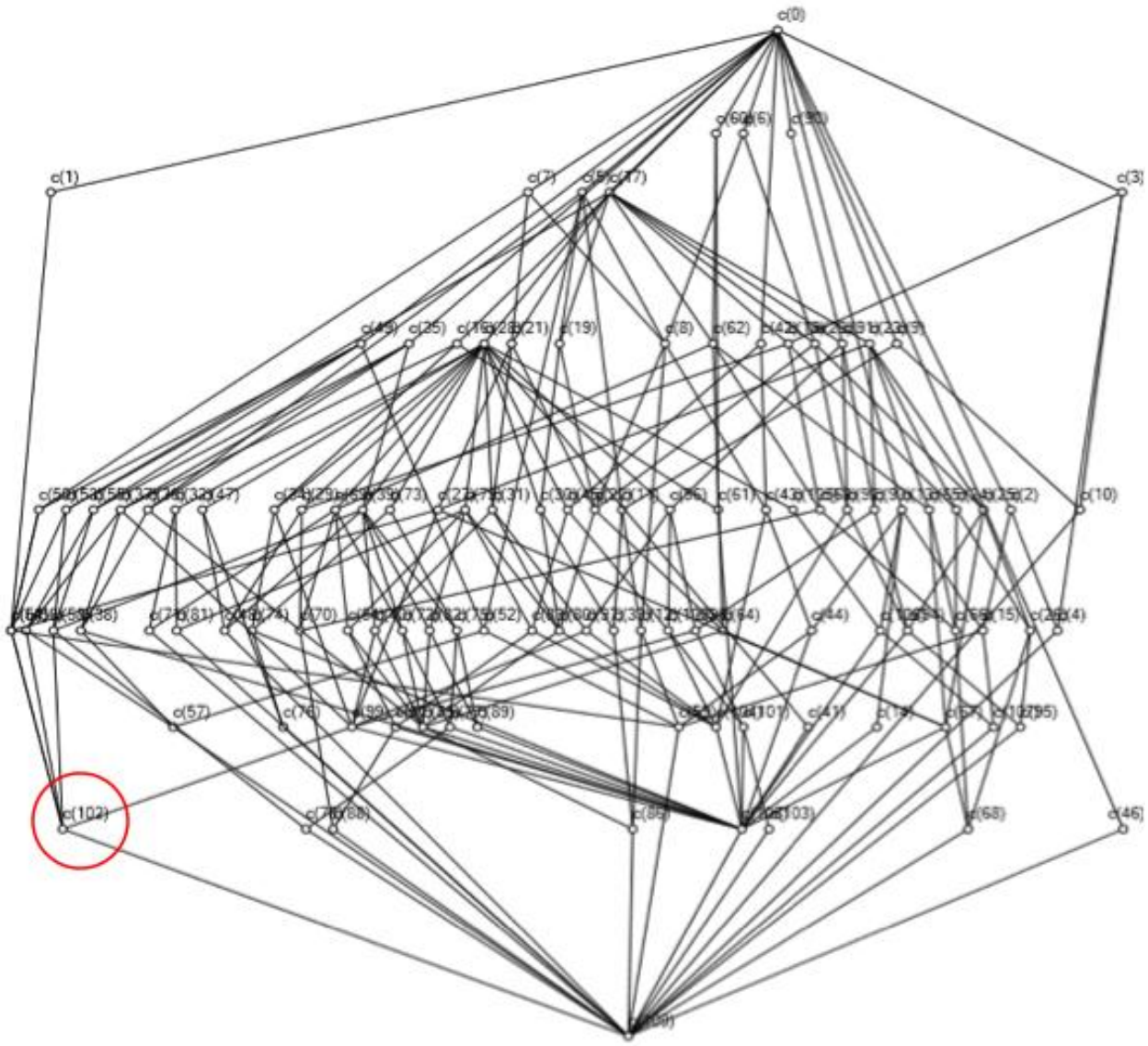

Figure 4.7 Galois lattices of Pivot Power

4.4.3. Interpretations of selected concepts

Interpretation of concept 102

The participant related to concept 102 (c(102)) is U10 only. U10 provided design features for Pivot Power. This concept includes information about power strip(P2), socket (P10), base

unit (P11), fuse(P12) and circuit breaker(P13). The relationships between parts above have externally connected (S2), partially overlapped (S4), or non-tangential proper position (S7). Provided types of functions by User10 are object-focused (F1), Transformation-based function (F2) Prohibition-based function(F3), and Relation-focused function (F5). This concept includes information about length (A31) for mentioned parts. Also, it includes the level of competition with regarding to technology both high and low (E211, E213). Table 4.8 shows participants and design features of concept 102 and Figure 4.8 shows detailed design features with exact wording by U10. Also, all the design features are highlighted on comments of U10 in Table 4.9.

Table 4.8 Participants and design features of concept 102

ConceptID	Extent	Intent
c(102)	{U10}	{P2; P10; P11; P12; P13; S2; S4; S7; F1; F2; F3; F5; A31; E211; E213}

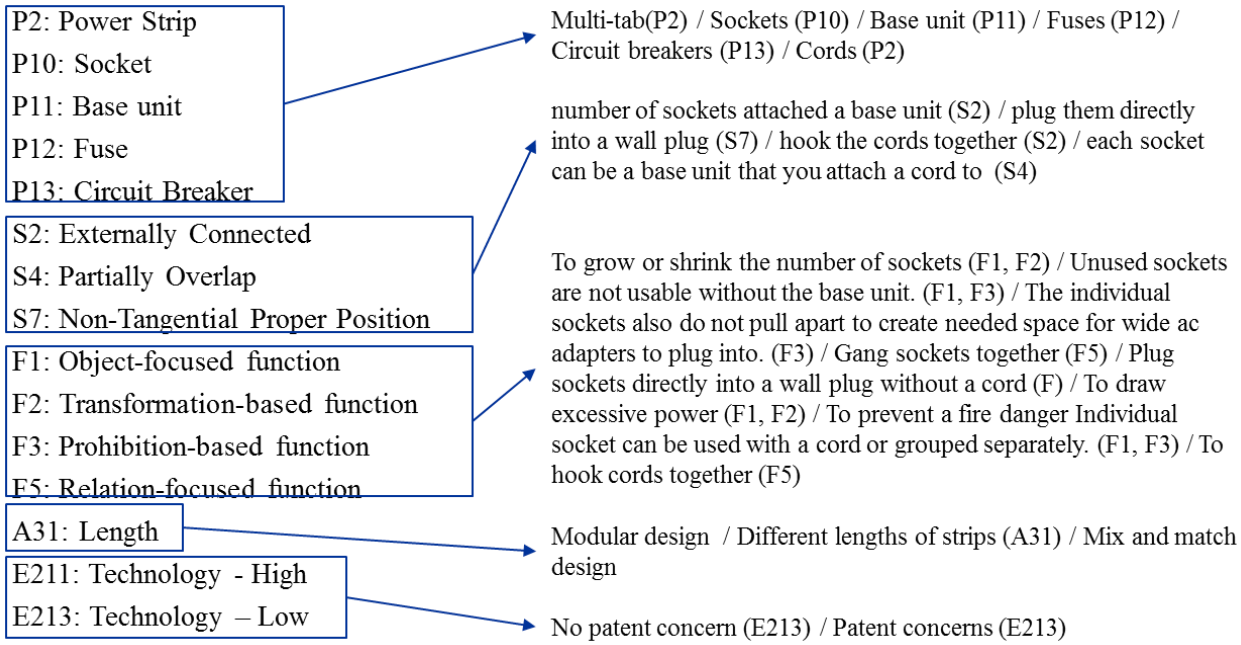

Figure 4.8 Detailed mentions of design features on comments by U10

Table 4.9 Comments of U10

	Comments of U10
1	From an advantage perspective the Multi-Tab allows you **to grow or shrink the number of sockets attached** a **base unit**. **The unused socket**s **are not usable without the base unit**. The individual sockets also do **not pull apart to create needed space for wide ac adapters to plug into**. The proposed design in effect does not have a **base unit**, but **each socket can be a base unit that you attach a cord to** or you can **gang them together and plug them directly into a wall plug** without a **cord** as shown in the drawing so you have no wasted parts like the Multi-Tab. From a **patent perspective**, I'm still not finding a patent or patent application for the designer "Soon Mo Kang". Given the proposed design is essentially "base less" and Multi-Tab is not leads me to believe that even if Kang has a patent, that it is not a factor.
2	Cool design. My guess is that the **patent** was **not for a modular design** strictly speaking, but for the cool **push button to extract the plug** since that is both novel and unexpected. There are **a number of older patents that have already covered modular power strips**. Would be curious to see the patent number for the Multi-Tab product. **Did not yet find it in Google patents**.
3	I think of the modular design as mainly adding function not available in the current products with beauty as a secondary feature. In looking at **power strips on Amazon.com there are currently 50 products.** None of them are modular as presented. What is also surprising is that there are 50! Why is something that is not typically visible with many not offering any significant advantage has so many variations? **The amount of effort that the 18 companies on Amazon alone are interested in producing and selling such a unforgettable product is amazing.** Seems like a good electrical design including **fuses or circuit breakers** would solve the problem of any number of outlets **drawing excessive power to prevent a fire danger**.
4	I wonder if going to a modular design where the **individual sockets could be used with a cord or grouped separately** and **usable without a cord**. If the product came with two cords you could build **different length** strips or maybe even be **able to hook the cords together** for a single strip with an extra long cord. Basically a **mix and match design**. The following graphic shows some of what is possible. <img src="http://farm4.static.flickr.com/3251/4562933787_8b539c2244.jpg">
5	Given the following product already exist and accomplishes what Jake had in mind. <img src="http://farm5.static.flickr.com/4069/4562933577_9371aa5447.jpg">

Interpretation of concept 17

Compared to concept 102, concept 17 has 23 participants and only one design feature, objective-focused function as shown in Table 4.10. This means that 45% of participants mentioned object-focused function for Pivot Power and eventually the conceptual design of Pivot Power should reflect the importance of realizing the purposive design features for Pivot Power. Table 4.11. shows comments related to design feature of object-focused function. Additionally, reduced comments to highlight a design feature – object-focused function are shown in Table 4.12.

Table 4.10 Participants and design features of concept 17

Concept	Participants	Design Features
c(17)	{U00; U06; U07; U09; U10; U11; U12; U13; U14; U15; U19; U23; U24; U32; U34; U35; U36; U39; U40; U46; U47; U49; U50}	{F1}

Table 4.11 Comments related to design feature 'F1'

Participant	Comment
U00	Have a look at the power strip under your desk. How many of its outlets are being used? How many of them would you like to use, but you can't, because a giant power brick (transformer) in the adjacent outlet is blocking it? It's a frustrating problem with which everyone who uses a desk is familiar. Several attempts have been made to solve it through creative designs, like the PowerSquid, but all of them fail in some regard (the squid creates a cluttered mess, and is unattractive at best). My solution is to put each outlet in its own cylindrical pod, and allow these pods to be either pushed up next to each other or pulled apart by a couple of inches. The mechanism to accomplish this would be a small section of tubing, inside of which the necessary wiring between outlets would be contained, that would connect each pair of neighboring pods, and could slide in and out of their sides. When collapsed into the pods it connects, the tube is hidden inside them, and the outlets are spaced as they would be on a traditional power strip. When extended, the outlets could accomodate large plugs like power bricks. This would allow the strip to always be as small as possible while still making

	all of its outlets available. Other features that are less necessary, but are part of my dream concept, include the ability to rotate each outlet within its pod for further flexibility - rather than sliding a pod apart from its neighbor, a user might simply swing the offending power brick out of the way. Another idea is for the strip's own power plug to contain a spool for winding up its wide, flat cable, allowing the Usable Power Strip to further minimize its clutter. Also on the plug is the strip's power switch, which is a flush-mounted slider, so the strip cannot be accidentally shut off when kicking around under the desk. Finally, I've made the outlets smile. You know you've always wanted to see it happen. Enjoy, and please offer feedback! I've been wanting to produce this 2006, so this is quite exciting.
U06	I have used the power squids and they're a mess. Your chords still get tangled and there's no real way to keep them organized and clean looking. The power strips are good because they keep everything close and easy to keep together, but you always have those plugs that are too wide and you can't get anything else in the spots on either side. It's frustrating at best. But this sounds like a great idea. I can keep all of my chords together and not worry about one or two spots not being used due to a large plug in. AWESOME JOB!
U07	Could you make the strip bendable, so it *could* be used in a circular configuration, or just bent in half back on itself, to save space? Maybe interlocking jointy things like the legs on a Gorillapod tripod? You could hang it off a desk, too, that way, but the pods would be big enough to keep it from bending back on itself too far to damage the wires. / Surge protection is a must - in the last couple years, having only had my computer plugged into a surge protector, I've lost a very expensive flat screen TV and some smaller appliances to power surges, and I live in a big city where I don't get lightning strikes directly. Surge protectors need to be everywhere.
U09	I like the bendable approach suggested by Catherine, but here are my 2 cents. / If the strip will be hanging from the wall like you have it, you are going to end up having a big mess of cables sticking out of the wall. / Most power strips are just that, and are not multifunctional, meaning, you can add some kind of cable management at the bottom of the strip that will allow you to bend around all the extra cables and maybe some kind of little runway to have them tucked nice and neat. / Good luck
U10	From an advantage perspective the Multi-Tab allows you to grow or shrink the number of sockets attached a base unit. The unused sockets are not usable without the base unit. The individual sockets also do not pull apart to create needed space for wide ac adapters to plug into. The proposed design in effect does not have a base unit, but each socket can be a base unit that you attach a cord to or you can gang them together and plug them directly into a wall plug without a cord as shown in the drawing so you have no wasted parts like the

	Multi-Tab. From a patent perspective, I'm still not finding a patent or patent application for the designer "Soon Mo Kang". Given the proposed design is essentially "base less" and Multi-Tab is not leads me to believe that even if Kang has a patent, that it is not a factor.
	Cool design. My guess is that the patent was not for a modular design strictly speaking, but for the cool push button to extract the plug since that is both novel and unexpected. There are a number of older patents that have already covered modular power strips. Would be curious to see the patent number for the Multi-Tab product. Did not yet find it in Google patents.
	I think of the modular design as mainly adding function not available in the current products with beauty as a secondary feature. In looking at power strips on Amazon.com there are currently 50 products. None of them are modular as presented. What is also surprising is that there are 50! Why is something that is not typically visible with many not offering any significant advantage has so many variations? The amount of effort that the 18 companies on Amazon alone are interested in producing and selling such a unforgettable product is amazing. Seems like a good electrical design including fuses or circuit breakers would solve the problem of any number of outlets drawing excessive power to prevent a fire danger.
	I wonder if going to a modular design where the individual sockets could be used with a cord or grouped separately and usable without a cord. If the product came with two cords you could build different length strips or maybe even be able to hook the cords together for a single strip with an extra long cord. Basically a mix and match design. The following graphic shows some of what is possible. <img src="http://farm4.static.flickr.com/3251/4562933787_8b539c2244.jpg">
	Given the following product already exist and accomplishes what Jake had in mind. <img src="http://farm5.static.flickr.com/4069/4562933577_9371aa5447.jpg">
U11	I was looking at redesigning the power strip and I was researching all the options in the market place because I hate what I own. I was definitely looking at a design that was flushed to the wall and had better spacing between sockets.
U12	So... Jake, lets make this one even more unique -- I do love the idea - and I have not yet bought any of those other ones... COULD there be a few USB outlets on it? I know that they are now selling wall outlets with it - and perhaps this could have one or two USB ones as well as the other 3-pronged ones The flat connection point to the wall is essential -- it makes me nuts that they are always big and bulky. I think you definitely have something here --

U13	How about adding some power killing power to appeal the green trends? In other words outlets that fully cut power when the adapter is leeching power when not in use.
U14	This is an amazing idea. I love to own one of these because my husband and I have electronics that use those brick type plugs. Having something that would give enough space or swivel it out of the way would be a godsend. No more having to buy more power strips because you can't use half of the plugs!
U15	Wow Jake - that's awesome! Nice job! / I should also mention in the interest of full disclosure that I have a competing idea this week./ I voted for your idea anyway :) I like this idea. / I HATE the fact that the "block" type power plugs only fit one or 2 on a regular power strip. / If this could be built and the extra money spent for the UL seal of approval. It would probably sell well...
U19	Fabulous design. The existing product displayed above by dond is rather inelegant IMHO. Function isn't everything. I like the idea of a flat plug for the wall. This works great when your outlet is behind furniture. I would suggest that the tops of the outlets are made in the twisty child proof style.
U23	Loving this idea. I checked out the other strips available, and think this one would be far superior even though the others have somewhat the same idea. First, the plug into the wall outlet is flush which is perfect for behind a desk. Also, the others are quite bulky while this design looks to slim things down. And, of course, there is always the outlet smiling :) By the way, I have the squid. And never use it. It's a mess, doesn't fit behind a desk, and everything gets tangled.
U24	This is such a great idea. Design elements could be incorporated to address a lot of the concerns. I especially like the idea of having individual outlets that could rotate to better accommodate different plug shapes/bricks. / I think this really comes down to design in terms of setting it apart from what's out there, and also price point. / Nice work!
U32	Over 40 comments! This is fantastic. Thanks for the great feedback everyone, and please keep it coming! In response to the latest ideas posted: when I initially developed this design, the concept of modularity of course came to mind â€“ but I decided against it. It seems that to accomplish a modular form, the pods would have to become much larger, contain much more technology, and simply wouldn't look as good on their own, with weird tongs sticking out of the side. The user would have to consider how many pods to buy, where to keep the extras, and the danger of too many plugs in one socket would indeed present itself. As for the "multi-tab" power strip, it's just a concept, so no threat there. Also, and this is key, my design is familiar to the user (I'd underline that if I could) - many of these other

concepts are missing this. I realize that none of them are in any way challenging to operate, but I don't want someone to approach my product and have to figure it out; I want it to simply be a power strip "plus," something that you get instantly. A design that does a few, clearly-defined things well is often better than one that balances too much function. But it could be that I'm just clinging to my baby, so to speak. And before someone else does, I figured I'd post another concept, this one to satisfy dond and Jason and the other modular fans out there: http://gizmodo.com/185733/design-concept-e+rope-modular-power-strip

I think that's what you were shooting for, right?

Thanks again, everyone!

I've seen both of these products, and I still think mine has advantages. Check my reply to Jason Ashton's similar comment above for my response to the Socket Sense.

Jason,

That's a tough one to answer. I have seen both of those products before - the second in particular is very close to my idea.

My issue with the first is that it's ill-suited for use under a desk. Notice it's pitched as a tabletop power adapter, "for meetings" â€“ its size and shape mean it will never fit in that crack between the desk and the wall. Unless you want to screw it under the tabletop and condemn yourself to fumbling around forever, it's not an option. Not to mention that power bricks, the impetus for these designs, would likely fall to the floor in this orientation.

The Socket Sense is functionally really similar to my design, but it seems that it's probably a low quality product - look at that beige plastic. It would absolutely solve the power brick problem, but it wouldn't exactly do it with style, or in a way that gives its owner much enjoyment. It also doesn't include the flexibility of rotating outlets.

I confess I've never owned the Squid (with this design in my head, I couldn't bring myself to buy it), but it seems to me that with it, what you gain in outlet count, you lose in organization. The idea of a power "strip" - an ordered, rigid row - makes more sense than the tangled knot of extension cords the Squid gives you. There's no way to become familiar with the Squid; each time it is used, the correct plug must be found. I would also imagine it creates a lot of clutter, and that its shape, essentially an egg with tails, makes it hard to find a position in which it will balance and rest comfortably under a desk.

Am I close?

	Looks like I responded before realizing that there was a Reply button. My answer is below.
	Thanks for the positive feedback! I feel I should also mention that this design received honorable mention in NASA's national Create the Future Design Contest back in 2008. Check it out here: http://www.createthefuturecontest.com/pages/view/entriesdetail.html?entryID=1091&previous=1 Thanks again and please keep the votes coming!
U34	Not too bad. I like that it's designed to be flexible to support different footprints connecting to the outlets while remaining rigid in its structure. The only thing is that alone, it doesn't quite stand out from existing products. Perhaps lighting indicators of which outlets are currently experiencing draw combined with color indication of what kind of ampere-draw a particular outlet is experiencing. Something to keep people energy conscious and give this particular idea more footing.
U35	I like it! I would assume that there is some kind of surge protection somewhere in line with the plugs. This would give you the fraction of an inch you always seem to be missing when using a typical power strip, After everything id plugged in you just mash it together to save space. Very nice.
U36	I haven't read all the comments, so in danger of duplicating I'm still gonna leave mine ; modular sockets: great (adding plugs that is) another angle of modular is; exchangable sockets for different countries (EU, US, SG, AU, etc) as we buy more and more global, this would hold the various plugs An OnOff switch per socket, so I could save power on adapters in the socket that still drain if no peripharal is attached.
U39	congrats. I still believe the cord is too small. Imagine using all the outlets ! It will be an electronic zoo. so consider this. / see my comments for mini / like this except cord is too small and outlets are many. Very unlikely you would have these many gadgets needing power so near each other. i have a multi outlet unit with six outlets but I cannot bring connection to them without an extension cord. so extend the lengthof the cord.
U40	I think it would be better if each outlet had its own switch to turn the outlet on or off, so at night or when not in use, you could stop energy usage of instant on appliances.
U46	Surely you would need to limit the amount you can expand the strip, otherwise you'd end up blowing/ tripping the fuse in the main consumer unit.
U47	Putting LED in each head (pivot) will help in identifying the defect in case of failure of any of the heads. that

	LED can show the flow of current. / yes! like it too! / haha / hehe!
U49	agree with this - or, perhaps the 'outlines' could illuminate?
U50	I like the new electronic pivot power but wonder if there is a way to outline the plug insertion points in white rather than have it all black. This would make it easier to plug something in when this is located in the back of an entertainment center. What do you think?

Table 4.12 Reduced comments to highlight function information

	Functions	**F1**
U00	To be pushed up next to each other / To be pulled apart by a couple of inches / **To connect each pair of neighboring pods** / **To slide in and out** / **To hide pods when collapsed** / **To accommodate large plugs when extended** / **To rotate each outlet within its pod** / **To wind its wide and flat cable** / **To minimize its clutter** / **Not to shut off accidently**	Yes
U06	**Not (to) get anything else in the spots** on either side	Yes
U07	Bendable / **To prevent from power surges**	Yes
U09	Cable management function **/ To bend around all the extra cables** / To tuck nice and neat	Yes
U10	To grow or shrink the number of sockets / Socket attached to a base unit / Unused sockets are not usable without the base unit. / The individual sockets also **do not pull apart to create needed space** for wide ac adapters to plug into. / Each socket can be a base unit that you attach a cord / **Gang sockets together** / Plug sockets directly into a wall plug without a cord	Yes
	To draw excessive power / **To prevent a fire danger**	Yes
	Individual socket can be used with a cord or grouped separately. / Usable without a cord / To hook cords together	
U11	**Have better spacing between sockets**	Yes
U12	**(To be) Pronged USB outlet**	Yes
U13	Power killing (**To kill power**)	Yes
U14	**Give enough space** (= reduce space) / Swivel out of the way	Yes
U15	**Not fit one or two on a regular power strip**	Yes
U19	**To work behind furniture** / **To provide 'child proof'**	Yes
U23	**Not to get tangled**	Yes
U24	**To be rotatable to (better) accommodate different plug shapes or bricks**	Yes
U32	**Use under a desk**	Yes
U34	**To support different footprints** / **Connect to the outlets** / Color indication / **Keep people energy conscious**	Yes
U35	Protect surge / **Save space**	Yes
U36	Exchangeable sockets / Available various plugs / **Save power**	Yes
U39	**Use all the outlets**	Yes
U40	**Save energy** / On-off function	Yes
U46	**Not to blow** / trip the fuse	Yes
U47	**Show flow of current** / **Help in identifying the defect in case of failure**	Yes
U49	**(To) Illuminate**	Yes
U50	**Easy to plug (= To plug easily)**	Yes

4.4.4. Participant Individual Score (PIS_i) and Participant Group Score (PGS) of Pivot Power

By the algorithm of PISi, all the PISi of participants in Pivot Power are calculated and displayed in Table 4.13. As the idea generator, U00 scored the highest PISi. Except U00, U32 score the second.

Table 4.13 Participant Individual Score in Pivot Power

Participant	PIS_i	Participant	PIS_i	Participant	PIS_i
U00	0.667	U17	0.352	U34	0.334
U01	0.402	U18	0.401	U35	0.333
U02	0.338	U19	0.355	U36	0.333
U03	0.341	U20	0.479	U37	0.332
U04	0.447	U21	0.446	U38	0.137
U05	0.336	U22	0.355	U39	0.142
U06	0.333	U23	0.338	U40	0.079
U07	0.342	U24	0.335	U41	0.153
U08	0.338	U25	0.344	U42	0.088
U09	0.444	U26	0.386	U43	0.083
U10	0.421	U27	0.333	U44	0.133
U11	0.341	U28	0.333	U45	0.079
U12	0.335	U29	0.441	U46	0.073
U13	0.366	U30	0.332	U47	0.034
U14	0.359	U31	0.334	U48	0.071
U15	0.352	U32	0.666	U49	0.090
U16	0.345	U33	0.334	U50	0.022

Tables 4.14 to 4.15 shows the lists of top 10 concepts generated by different perspectives: (1) participant group score, (2) number of design features, and (3) number of participants respectively. PGS-based list (1) and design feature-based (2) list have two common concepts, while no common concept exists between PGS-based list (1) and participant-based list (3). This means that if PGS applies to the generated concepts, it causes the significant differences in the perspective of participant only.

Table 4.14 Top 10 Concepts from generated concepts based on participant group score (PGS)

ConceptID	Participant	Design Features	PGS
c(102)	{U10}	{P2; P10; P11; P12; P13; S2; S4; S7; F1; F2; F3; F5; A31;	0.667

		E211; E213}	
c(89)	{U00; U40}	{P3; P6; S7; F1; F2}	0.666
c(78)	{U36}	{P6; P7; P10; S7; F1; F2; F4}	0.666
c(33)	{U12; U19}	{F1; F2; A14; A33}	0.555
c(14)	{U00; U22}	{A12; E123}	0.544
c(108)	{U00}	{P1; P2; P3; P4; P5; P6; P7; P8; S1; S2; S4; S5; S7; F1; F2; F3; F5; A12; A31; A32; A33; E123}	0.511
c(70)	{U14; U35}	{P7; F1; F2; E11}	0.510
c(98)	{U00; U07; U10}	{P2; F1; F2; F3}	0.505
c(87)	{U00; U35}	{P3; P7; S1; F1; F2}	0.504
c(54)	{U10; U46}	{P10; F1; F3; A31}	0.504

Table 4.15 Top 10 Concepts from generated concepts based on the number of design features except problem initiator's concept)

ConceptID	Participant	Design Features
c(102)	{U10}	{P2; P10; P11; P12; P13; S2; S4; S7; F1; F2; F3; F5; A31; E211; E213}
c(59)	{U28}	{P10; P14; S1; A11; A12; A14; A15; A31; A32; A33; E12; E122; E211}
c(99)	{U00; U10}	{P2; S2; S4; S7; F1; F2; F3; F5; A31}
c(86)	{U12}	{P3; P7; S7; F1; F2; A14; A31; A32; A33}
c(85)	{U00; U12}	{P3; P7; S7; F1; F2; A31; A32; A33}
c(104)	{U00; U39}	{P2; P3; S1; F1; F2; A31; A32; A33}
c(68)	{U23}	{P7; F1; F3; A31; A32; A33; E11}
c(78)	{U36}	{P6; P7; P10; S7; F1; F2; F4}
c(80)	{U00; U12; U39}	{P3; F1; F2; A31; A32; A33}
c(67)	{U00; U23}	{P7; F1; F3; A31; A32; A33}

Table 4.16 Top 10 Concepts from generated concepts based on the number of participants who mentioned the same design feature(s)

ConceptID	Participants	Design Features
c(17)	{U00; U06; U07; U09; U10; U11; U12; U13; U14; U15; U19; U23; U24; U32; U34; U35; U36; U39; U40; U46; U47; U49; U50}	{F1}
c(3)	{U02; U04; U05; U06; U14; U15; U16; U20; U23; U25; U26; U31; U33; U35; U37; U38; U42; U44; U47; U48}	{E11}
c(28)	{U00; U07; U09; U10; U11; U12; U13; U14; U19; U24; U32; U34; U35; U36; U39; U40; U47; U49; U50}	{F1; F2}
c(60)	{U00; U03; U12; U14; U15; U23; U35; U36; U50}	{P7}
c(62)	{U00; U12; U14; U15; U23; U35; U36; U50}	{P7; F1}
c(5)	{U00; U11; U12; U17; U19; U23; U28; U39}	{A33}
c(79)	{U00; U12; U13; U24; U35; U39; U40}	{P3; F1; F2}
c(23)	{U00; U06; U07; U10; U15; U23; U46}	{F1; F3}
c(7)	{U00; U10; U12; U23; U28; U39; U46}	{A31}
c(35)	{U00; U10; U12; U17; U36; U40; U47}	{S7}

4.5 Validation

In this section, the experiment for validating the proposed methods in previous section 4.3 was conducted.

4.5.1. Objective

The objectives of this validation is (1) to identify whether the design features in the proposed formalism can be used in a practical conceptual design process and also (2) to identify whether the provided participant individual score and participant group scores can be used in a practical conceptual design process with design features.

4.5.2. Data Sets

In order to collect data for validation, Focus Group Interview (FGI) was conducted with four experts – two industrial design professors, one graduate level student in industrial design department and one graduate level student by detailed questionnaire and video conferences. They evaluated every design features of the proposed taxonomy in section 4.2 with 0-10 scale based on the influences of those features to improve the initial idea to realize as a commercialized product, Pivot Power. The detailed questionnaire is available at Appendix A.

Three test datasets are developed: (1) two control group datasets – design features only and design features enhanced by participant group score, and (2) one comparison group dataset from experts.

Test dataset_1: Assign a value to each design feature used in formal concept analysis based on the frequency mentioned in crowdsourcing design activities (problem statements and comments) and then normalize assigned values to 0-1 scales.

Test dataset_2: Assign a value to each design feature used in formal concept analysis based on the frequency mentioned in crowdsourcing design activities (problem statements and comments) and the user values used in the case study and then normalize assigned values to 0-1 scales.

Test dataset_3: By a design expert group (4 experts), each design feature is evaluated in 0-10 scale based on the importance of the feature which influenced on the product development design decision-making and then normalize assigned values to 0-1 scales. If the normalized score of design feature by expert evaluation is greater than 0.5 as a threshold, it was categorized as 'Useful' design feature in crowdsourcing design activities. Total 13 design features were selected as useful design features. The same numbers of 'useful' design features were applied to other two test datasets.

4.5.3. Evaluation Metrics

For this experiment, the indicators of *precision*, *recall*, and *F-measure* to measure the performance of the proposed method [van Rijsbergen, 1979].

$$precision = \frac{a}{a+b} \tag{4.21}$$

$$recall = \frac{a}{a+c} \tag{4.22}$$

$$F-measure = \frac{2 \times precision \times recall}{precision+recall} = \frac{2a}{2a+b+c} \tag{4.23}$$

, where a is true positive, b is false positive, and c is false negative.

For the purpose of this experiment I, a is a certain design feature in design features only or in design features with PGS is 'useful' design feature and also that design feature was indicated by expert as useful one, b is a certain design feature in design features only or in design features with PGS is categorized as a 'useful' design feature and also the same design feature was not indicated by expert as useful one, and c is a certain design feature in any datasets are not considered as 'useful' one at all. Datasets for precision and recall test are shown in Table 5.17.

Table 4.17 Normalized scores, ranks, and precision and recall test

	Normalized scores			Ranks from normalized scores			Precision and Recall				
	DF Only	DF+P	Experts	DF Only	DF+P	Experts	DF Only	DF+P	Experts	DF Only vs. Experts	DF+P vs. Experts
P1	0.07	0.05	0.38	13	19	19	Y	N	N	FP	TN
P2	0.02	0.22	0.63	25	9	12	N	Y	Y	FN	TP
P3	0.04	0.20	1.00	21	10	1	N	Y	Y	FN	TP
P4	0.02	0.01	0.25	25	30	29	N	N	N	TN	TN
P5	0.02	0.01	0.38	25	30	19	N	N	N	TN	TN
P6	0.04	0.12	0.00	21	16	37	N	N	N	TN	TN
P7	0.15	0.29	0.25	11	5	29	Y	Y	N	FP	FP
P8	0.02	0.01	0.00	25	30	37	N	N	N	TN	TN
P9	0.02	0.01	0.00	25	28	37	N	N	N	TN	TN
P10	0.04	0.17	0.75	21	12	4	N	Y	Y	FN	TP
P11	0.02	0.01	0.13	25	36	34	N	N	N	TN	TN
P12	0.02	0.01	0.00	25	36	37	N	N	N	TN	TN
P13	0.02	0.01	0.00	25	36	37	N	N	N	TN	TN
P14	0.02	0.01	0.00	25	33	37	N	N	N	TN	TN
P15	0.02	0.04	0.00	25	22	37	N	N	N	TN	TN
P16	0.00	0.01	0.00	40	28	37	N	N	N	TN	TN
S1	0.16	0.18	0.75	10	11	4	Y	Y	Y	TP	TP
S2	0.05	0.04	0.88	15	24	2	N	N	Y	FN	FN
S3	0.00	0.00	0.25	40	41	29	N	N	N	TN	TN
S4	0.05	0.04	0.75	15	24	4	N	N	Y	FN	FN
S5	0.02	0.03	0.38	25	26	19	N	N	N	TN	TN
S6	0.00	0.00	0.38	40	41	19	N	N	N	TN	TN
S7	0.29	0.28	0.13	7	6	34	Y	Y	N	FP	FP
S8	0.00	0.00	0.13	40	41	34	N	N	N	TN	TN
F1	1.00	1.00	0.75	1	1	4	Y	Y	Y	TP	TP
F2	0.87	0.66	0.75	2	2	4	Y	Y	Y	TP	TP
F3	0.35	0.26	0.50	6	8	14	Y	Y	N	FP	FP
F4	0.02	0.01	0.25	25	40	29	N	N	N	TN	TN
F5	0.20	0.16	0.38	9	14	19	Y	N	N	FP	TN
A11	0.02	0.01	0.00	25	33	37	N	N	N	TN	TN
A12	0.09	0.12	0.75	12	15	4	Y	N	Y	TP	FN
A13	0.00	0.00	0.75	40	41	4	N	N	Y	FN	FN
A14	0.05	0.08	0.50	15	17	14	N	N	N	TN	TN
A15	0.05	0.04	0.38	15	23	19	N	N	N	TN	TN
A2	0.05	0.05	0.75	15	20	4	N	N	Y	FN	FN
A31	0.42	0.33	0.88	3	3	2	Y	Y	Y	TP	TP
A32	0.36	0.28	0.63	5	7	12	Y	Y	Y	TP	TP
A33	0.40	0.30	0.38	4	4	19	Y	Y	N	FP	FP
E11	0.22	0.17	0.25	8	13	29	Y	Y	N	FP	FP
E12	0.07	0.06	0.38	13	18	19	Y	N	N	FP	TN
E122	0.02	0.01	0.38	25	33	19	N	N	N	TN	TN
E123	0.04	0.02	0.38	21	27	19	N	N	N	TN	TN
E211	0.05	0.05	0.50	15	21	14	N	N	N	TN	TN
E212	0.00	0.00	0.50	40	41	14	N	N	N	TN	TN
E213	0.02	0.01	0.50	25	36	14	N	N	N	TN	TN

4.5.4. Results of Experiment I

The experimental results are illustrated in Table 4.18 and Table 4.19. According to the data in Table 4.19, the precision and recall values in 'DF+P vs. Expert' improved markedly 18.6% and 15.3% respectively compared to the values in 'DF only vs. Expert' by applying Participant Group Score. Also, all the values of precision, recall, accuracy, and F-measure in DF+P vs. Expert are superior to the values in DF Only vs. Expert (Figure 4.9).

Table 4.18 Counts of true positives (TP), false negatives (FN), false positives (FP), and true negatives (TN)

	DF Only vs. Expert	**DF+P vs. Expert**
TP	6	8
FN	7	5
FP	8	5
TN	24	27

Table 4.19 Result of precision and recall test

	DF Only vs. Expert	**DF+P vs. Expert**
PRECISION	0.429	0.615
RECALL	0.462	0.615
ACCURACY	0.667	0.778
F-MEASURE	0.444	0.615

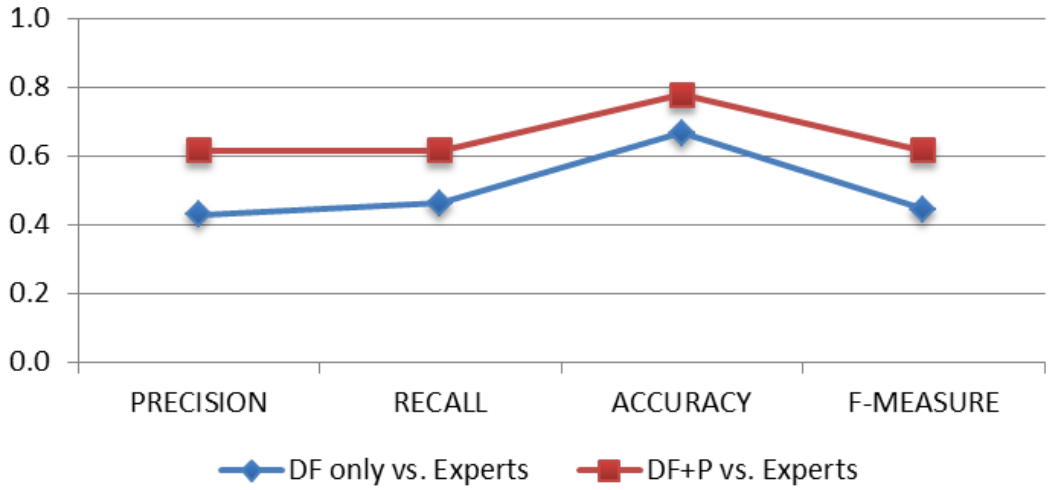

Figure 4.9 Result chart of precision and recall test

4.5.5. Experiment II: without threshold

Experiment I in section 4.5.3 was conducted with a threshold, 0.5 to compare with top 13 rankers in each score group. To make the result more in general, however, the experiment should be conducted without any threshold and compared with the possibility of higher experimental metric values.

4.5.6. Results of Experiment II

Results of experiment II are shown in Table 4.21. Since this experiment was conducted without any threshold, total 45 times calculations were performed as the number of design features. Among 45 times, the percentage that the case of design features with PGS is greater than that of design feature only for four metrics, precision, recall, accuracy, and F-measure were 80%, 46.7%, 73.3%, and 55.8% respectively. These results show that the enhanced information about design

features for crowdsourcing design should be considered together for the information of participants.

Table 4.20 Number of rankers and percentage of design features with PGS is better than Design features only

	DF+P ≥ DF only	Percentage
PRECISION	36	80
RECALL	21	46.7
ACCURACY	33	73.3
F-MEASURE	24	55.8

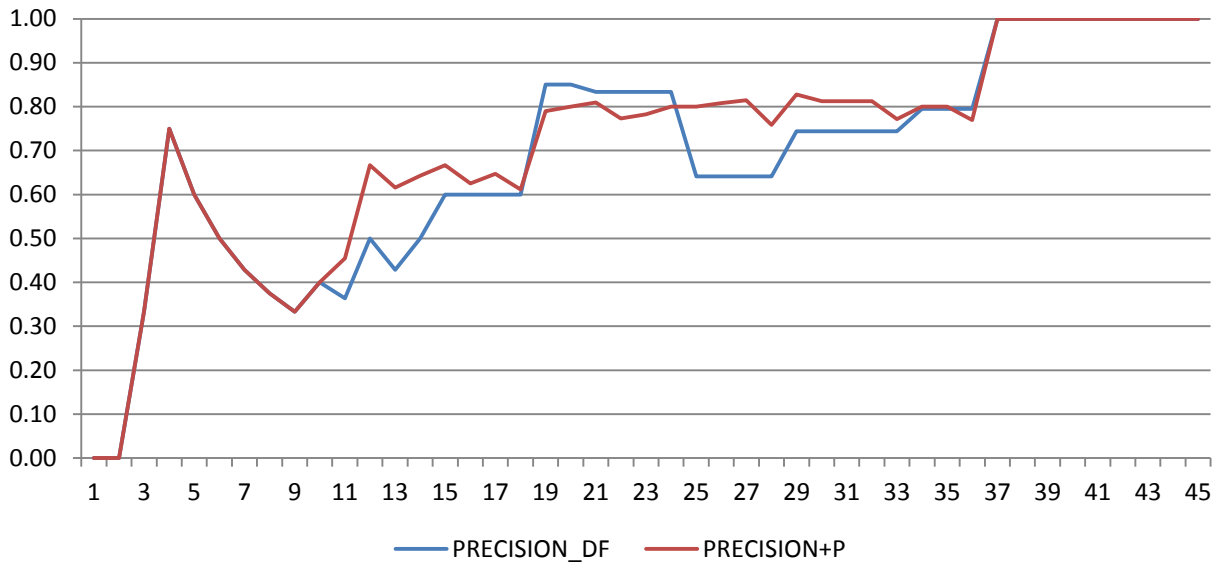

Figure 4.10 Comparison chart of precision between design features only and with PGS

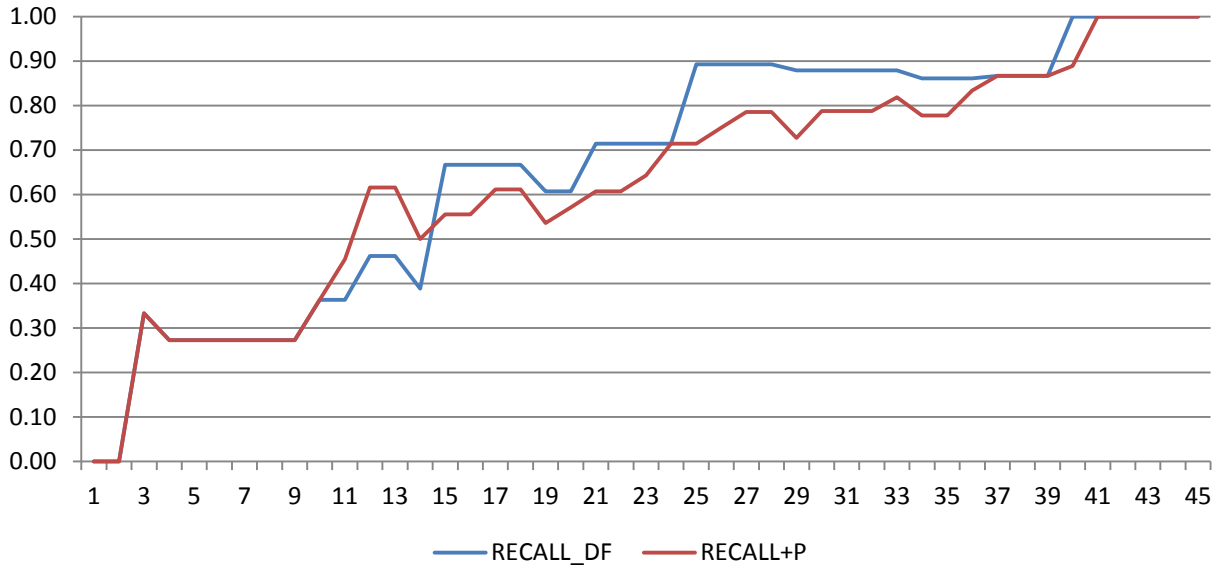

Figure 4.11 Comparison chart of recall between design features only and with PGS

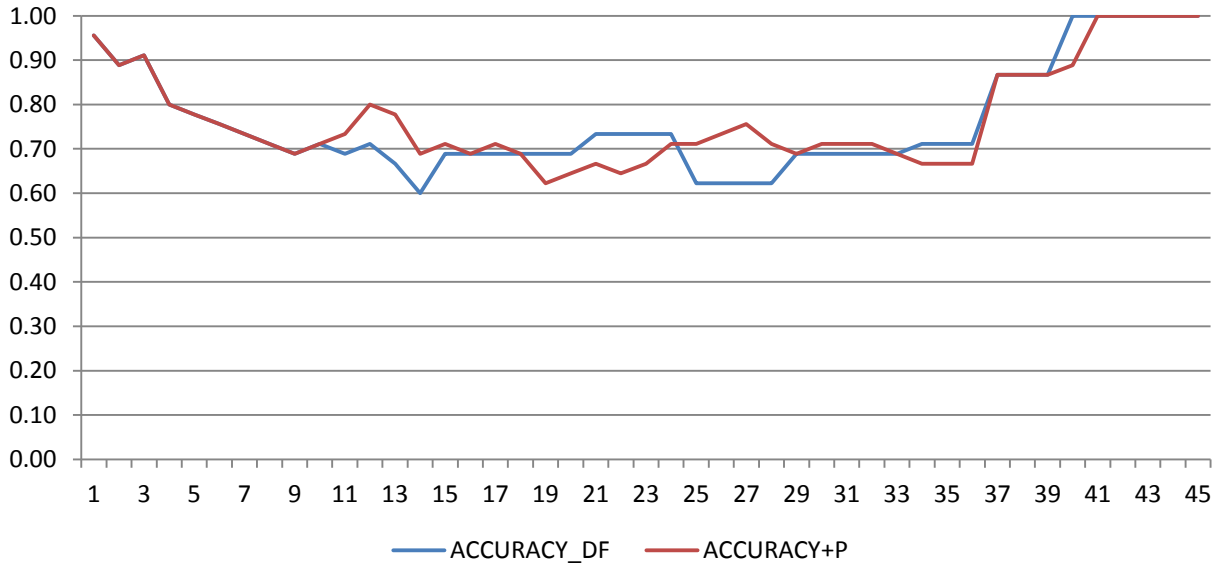

Figure 4.12 Comparison chart of precision between design features only and with PGS

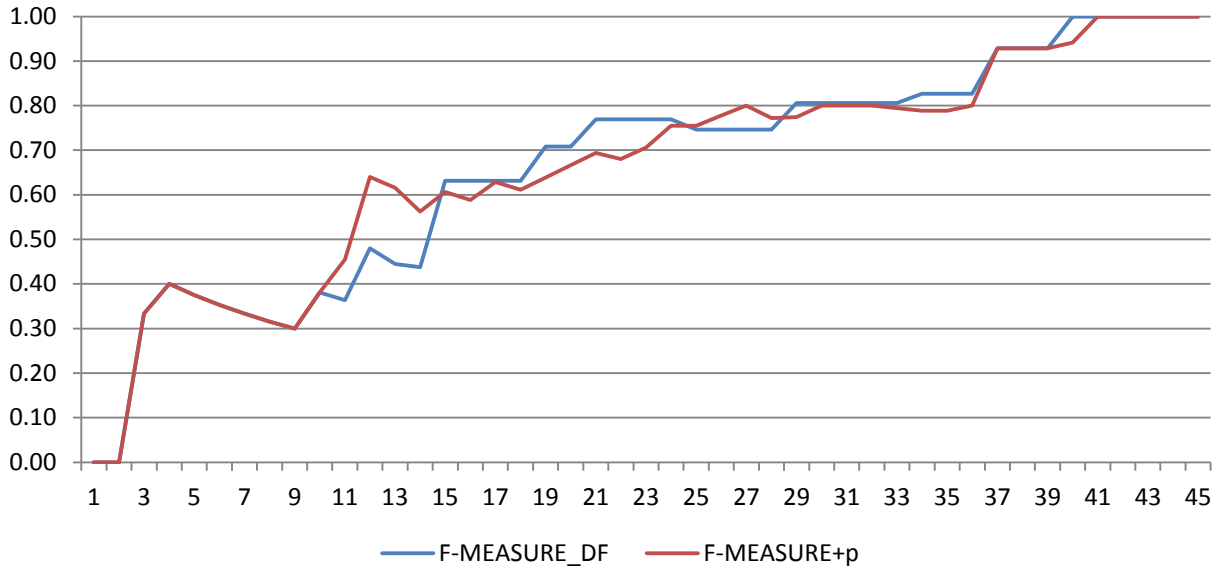

Figure 4.13 Comparison chart of precision between design features only and with PGS

Table 4.21 Comparison table of precision, recall, accuracy, and F-measure without threshold between Design Features only and design features with *PGS*

	DF Only				DF+P			
No. Ranks	PRECISION	RECALL	ACCURACY	F-MEASURE	PRECISION	RECALL	ACCURACY	F-MEASURE
1	0.00	0.00	0.96	N/A	0.00	0.00	0.96	N/A
2	0.00	0.00	0.89	N/A	0.00	0.00	0.89	N/A
3	0.33	0.33	0.91	0.33	0.33	0.33	0.91	0.33
4	0.75	0.27	0.80	0.40	0.75	0.27	0.80	0.40
5	0.60	0.27	0.78	0.38	0.60	0.27	0.78	0.38
6	0.50	0.27	0.76	0.35	0.50	0.27	0.76	0.35
7	0.43	0.27	0.73	0.33	0.43	0.27	0.73	0.33
8	0.38	0.27	0.71	0.32	0.38	0.27	0.71	0.32
9	0.33	0.27	0.69	0.30	0.33	0.27	0.69	0.30
10	0.40	0.36	0.71	0.38	0.40	0.36	0.71	0.38
11	0.36	0.36	0.69	0.36	0.45	0.45	0.73	0.45
12	0.50	0.46	0.71	0.48	0.67	0.62	0.80	0.64
13	0.43	0.46	0.67	0.44	0.62	0.62	0.78	0.62
14	0.50	0.39	0.60	0.44	0.64	0.50	0.69	0.56
15	0.60	0.67	0.69	0.63	0.67	0.56	0.71	0.61
16	0.60	0.67	0.69	0.63	0.63	0.56	0.69	0.59
17	0.60	0.67	0.69	0.63	0.65	0.61	0.71	0.63
18	0.60	0.67	0.69	0.63	0.61	0.61	0.69	0.61
19	0.85	0.61	0.69	0.71	0.79	0.54	0.62	0.64
20	0.85	0.61	0.69	0.71	0.80	0.57	0.64	0.67
21	0.83	0.71	0.73	0.77	0.81	0.61	0.67	0.69
22	0.83	0.71	0.73	0.77	0.77	0.61	0.64	0.68

23	0.83	0.71	0.73	0.77	0.78	0.64	0.67	0.71
24	0.83	0.71	0.73	0.77	0.80	0.71	0.71	0.75
25	0.64	0.89	0.62	0.75	0.80	0.71	0.71	0.75
26	0.64	0.89	0.62	0.75	0.81	0.75	0.73	0.78
27	0.64	0.89	0.62	0.75	0.81	0.79	0.76	0.80
28	0.64	0.89	0.62	0.75	0.76	0.79	0.71	0.77
29	0.74	0.88	0.69	0.81	0.83	0.73	0.69	0.77
30	0.74	0.88	0.69	0.81	0.81	0.79	0.71	0.80
31	0.74	0.88	0.69	0.81	0.81	0.79	0.71	0.80
32	0.74	0.88	0.69	0.81	0.81	0.79	0.71	0.80
33	0.74	0.88	0.69	0.81	0.77	0.82	0.69	0.79
34	0.79	0.86	0.71	0.83	0.80	0.78	0.67	0.79
35	0.79	0.86	0.71	0.83	0.80	0.78	0.67	0.79
36	0.79	0.86	0.71	0.83	0.77	0.83	0.67	0.80
37	1.00	0.87	0.87	0.93	1.00	0.87	0.87	0.93
38	1.00	0.87	0.87	0.93	1.00	0.87	0.87	0.93
39	1.00	0.87	0.87	0.93	1.00	0.87	0.87	0.93
40	1.00	1.00	1.00	1.00	1.00	0.89	0.89	0.94
41	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
42	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
43	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
44	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
45	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

4.6. Conclusion

4.6.1. Summary

This chapter presents a method, Formal Concept Analysis, to represent concepts generated in crowdsourcing design activities with taxonomy of design features. The taxonomy addressed in this chapter includes extended design features for adopting into crowdsourcing design environment. In addition, using Formal Concept Analysis approach, the relationship between participants and design features to consist a design concept in crowdsourcing design are more clearly identified. A case study with Pivot Power, an actual product developed by crowdsourcing design, also has been conducted to show that the proposed method is applicable to a practical environment.

In order to validate the usability of the proposed method and participant information, precision and recall tests are conducted through Focus Group Interview. As the result, the proposed method which includes participant information as participant group score (PGS) are meaningfully applicable to crowdsourcing design environment.

4.6.2. Contribution

In this chapter, two contributions can be addressed. A major contribution is to provide a method to represent and extract concepts in crowdsourcing design activities. Since the proposed method can generate concepts from the sparse pieces of data or information, one of the major constraints of crowdsourcing design, limited amount of information, can be overcome through this method. The second contribution is to apply participant information based on the activities in crowdsourcing design platform. Because of non-guaranteed quality of participants, it is difficult to adopt the ideas or comments with convince of the quality. However, using participant individual score and participant group score that were proposed in this method, non-guaranteed quality of participants can be resolved.

CHAPTER 5.

DISCUSSION AND CONCLUSION

5.1. Discussion

5.1.1. Summary

The purpose of crowdsourcing design is to develop a design idea by improving or solving current problems with the vast knowledge of crowds and to realize it as a commercialized product. Unlike the conventional product design processes, the crowdsourcing design is performed in the open innovation environment. In crowdsourcing design as an open innovative environment, the crowds have their own characteristics by activities of participants – sparsity, anonymity, and non-guaranteed quality [Li and Hongjuan, 2011; Peterson and Ingomar, 2013]. This being so, understanding design features that are discussed in crowdsourcing design and identifying the activities of participants are critical to overcome the characteristics and limitations.

In order to tackle the problems above, this research focuses on following questions: (1) how crowdsourcing design activities of participants are captured as design information to develop a product in crowdsourcing platform in the perspectives of process and elements, and (2) how a system systematically extracts and represents the explicit or implicit hidden design concepts from crowdsourcing design activities.

The first question is mainly tackled by applying socio-technological approach, Actor Network Theory. The activities in a crowdsourcing design platform or thread are able to analyze by translation process in ANT. Especially participants as human actors play an important role in

this collaborative design environment to bind other potential contributors in order to realize their own purpose, 'commercialization of generated product idea'. With two points of view, process and element, a descriptive formalism is provided. Using this formalism, participants' activities can be predictable, because the process view is explained by the activities in crowdsourcing design with the relation of necessity and sufficiency including causality. Along with the process view, the element view provided to specify the roles of participants in crowdsourcing design. Since participants who have sufficient design knowledge related to the initiated product design ideas explicit themselves to crowdsourcing design platform by comments or other contributing methods spontaneously, two types of elements – identification and design information of participant – are helpful to understand participants more in detail. The proposed formalism adopted translation in ANT also shows the possibility of combining human- and non-human actors in a sense of collaboration. By formal concept analysis method in chapter 4, the answer for the first question is abundant. Since design features that are commonly mentioned by specific participants as well as participants' interests on specific design features generate participant groups, design features as non-human actors are able to play a significant role in crowdsourcing design. In addition, Participant Individual Score or Participant Group Score is also applicable to enhance the understanding of participants by metrics of time, reputation, and task-fitness. Those scores involve the historical backgrounds and activities of participants in a crowdsourcing design platform.

In order to answer the second question, two approaches are provided: taxonomy of design features for crowdsourcing design including participant information and formal concept analysis method for extracting concepts from crowdsourcing design activities. As the results, implicit concepts as well as explicit ones are extracted from those activities. Explicit concepts are

extracted from the direct mentions of participants about design features, while implicit concepts are usually extracted from the combined design features which indirectly related pieces of information. In other words, from the limited amount of design feature information, potential concepts to improve proposed product ideas are extracted. This result can be a possible solution for one of global limitations in crowdsourcing design, 'sparsity'. A design feature argued and discussed by many participants means that this specific design concept can be a significant concept, even though it has only one design feature. In other words, if one element design concept includes many valuable participants, this concept is able to be a critical one. As a method to assist the process of finding significant meaning from information sparsity environment, formal concept analysis is usefully applicable.

Although positive applicable situations exist and its usefulness in crowdsourcing design, formal concept analysis method has a couple of limitations. Basically, since formal concept analysis is conducted and explained by binary relations between intent (design feature) and extent (participant), if the attributes or features have continuous values, it requires more efforts to apply into crowdsourcing design. Though fuzzy logic approach has been applied to formal concept analysis to overcome these challenges successfully [Bělohlávek, 2004], it can generate another problem to increase numbers of intents (design features) rapidly. Therefore, set approximation theory or rough set theory can be an alternative approach to resolve this problem [Yao and Chen, 2006; Shao et al., 2007; Yamaguchi, 2009; Dubois and Prade, 2012].

5.1.2. Contributions

The overall contribution of this research is to open the stage for considering crowdsourcing design as a united platform of developing design concepts among all possible

actors from participants to design features. By analyzing formal design concepts and behavior of participants in crowdsourcing design with formal analysis methods, the ultimate purpose of this research to provide a systematical approach to understand the nature of crowdsourcing design and to enhance the crowdsourcing design environment is fulfilled. The increased understanding of participants' behavior by analytic approach adopted from Actor Network Theory helps to communicate between participants each other based on the stage of processes. The proposed formalism with element perspective also enriches the understanding level of participants' activities, since that formalism represents the amount of design knowledge on a specific crowdsourcing design.

Aforementioned, contributions of this research proceed to impact on industry in three folds. The first expected impact is to redefine the definition of designer in crowdsourcing design or in open innovative design environment. Conventionally, product designers are considered as highly skilled and educated experts to describe a physical and non-physical concept of product design. On the contrary, by the proposed analysis for participants to present the development of design concepts with other crowds, it is clarified that any participants can contribute in any aspects in the process of design with their own activities even though it is considered as a trivial one such as compliment or voting.

The second impact is to provide the strategies of how to build and design the detailed services on current crowdsourcing platforms with the increase understanding of participants' behavior. To encourage the activities in current crowdsourcing design platform, the proposed metrics for participants such as time, reputation, and task-fitness are applicable to make that the benefits or rewards in crowdsourcing services are transparently provided to participants.

The third impact on industry from this research is to provide a novel breakthrough to understand the voice of customer by their design activities in the communities on conventional manufacturing companies. Not even for new product development or design, but for maintaining and improving current products for a company, the obtainment and analysis of the voice of the customers are critical. Since the processes of collecting and analyzing the voice of customers are similar to the activities in crowdsourcing design and other open innovative collaboration, the proposed methods and formalisms are applicable to current manufacturing industry.

Additionally, the impacts on academia through this research are also expected. Main impact comes from the approach of interdisciplinary research effort to apply social science theory directly to design and engineering domain by the analogy analysis. As the crowdsourcing and other social network services are prevailed, the requirement for the approaches to identify activities in these environments is also increased a lot. In this situation, the attempts to apply the theories of social science to engineering and design fields can be a breakthrough.

The second impact in academia is more specific. By the contributions of this research, non-human actors or features are applicable to analyze the human behaviors in crowdsourcing and online communities. By setting the stage for considering a set of design features as a leading factor to analyze and understand the participants with provided taxonomy of novel design features for crowdsourcing design and the formal concept analysis method to extract potential concepts generated from crowdsourcing design activities.

In sum, the contributions and the impacts of this research would result in great assistance from anonymous crowds to design and for engineering experts.

5.2. Future Research Direction

While this research has made significant contributions by providing a novel approach to meet the current demands on crowdsourcing design environment in the theoretical perspectives, there are limitations that need to be considered and opportunities for further research.

Regarding to translation in Actor Network Theory, two research directions can be proposed. First, the analysis of translation in Actor Network Theory in this research conducted based on the assumption of one time occurrence. However, in practice, since the translations in crowdsourcing design occur repeatedly, the changes of actor network are represented by the perspective of time. This means that the representation of approach for nested Actor Network is required. With the time series information, the novel approach will provide in-depth and comprehensive understanding of crowdsourcing design activities. Second, the boundary of crowdsourcing design in this research is also set as a crowdsourcing design thread, not a full crowdsourcing design platform. However, the knowledge or expertise of participants is manifested in various design projects throughout the entire crowdsourcing platform. Therefore, the research opportunity to analyze the relationship between design threads and furthermore between crowdsourcing design platforms including embedded actor information of participants and design features are remained behind.

Regarding the formal concept analysis method, an additional research direction can be suggested. Since the feature extraction from crowdsourcing design thread in this research is performed semi-automatically, it is required to extract design feature information automatically from participant's contributions using natural language process in order to develop formal context as the research opportunity.

APPENDICES

APPENDIX A. QUESTIONNAIRE FOR FOCUS GROUP INTERVIEW WITH EXPERTS

Understanding for Applying Design Features in Crowdsourcing Design

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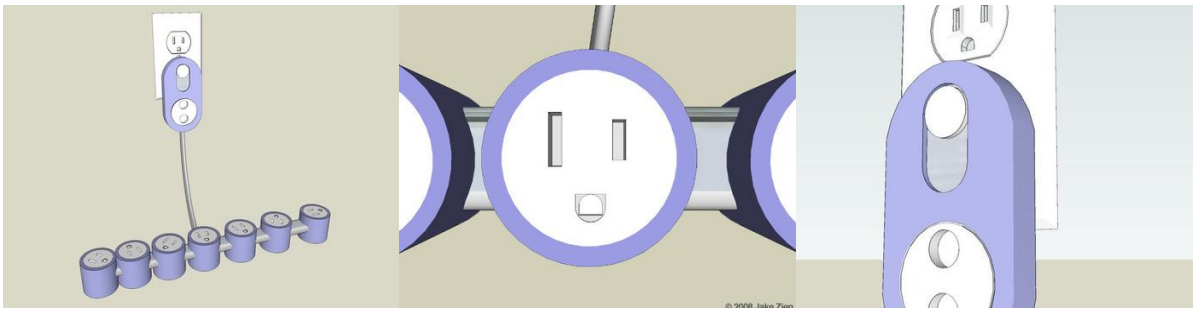
The purpose of this questionnaire is to confirm what kinds of design factors are considered during the process of product development from conceptual design to final commercial product launch conducted through the on-line collaboration. Based on the understanding of provided images, please answer the questions.

Screenshots of Initial Concept Design

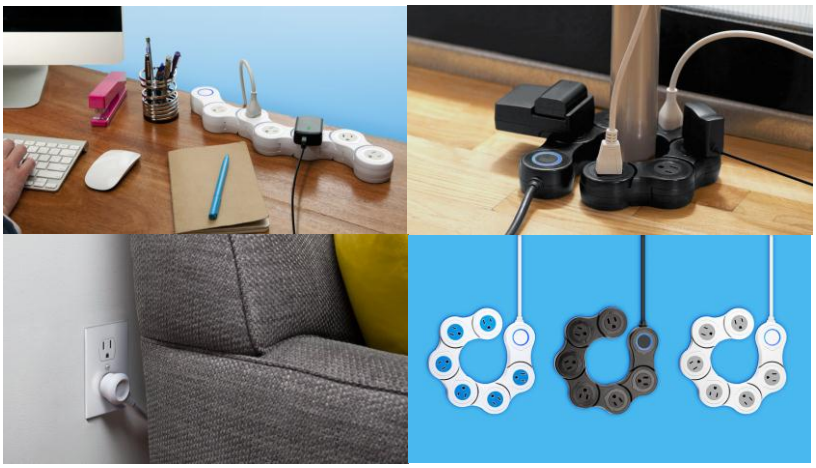


This description provided by non-expert idea generator. It is provided to help you for understanding initial concept design.

Have a look at the power strip under your desk. How many of its outlets are being used? How many of them

would you like to use, but you can't, because a giant power brick (transformer) in the adjacent outlet is blocking it? It's a frustrating problem with which everyone who uses a desk is familiar. Several attempts have been made to solve it through creative designs, like the PowerSquid, but all of them fail in some regard (the squid creates a cluttered mess, and is unattractive at best). My solution is to put each outlet in its own cylindrical pod, and allow these pods to be either pushed up next to each other or pulled apart by a couple of inches. The mechanism to accomplish this would be a small section of tubing, inside of which the necessary wiring between outlets would be contained, that would connect each pair of neighboring pods, and could slide in and out of their sides. When collapsed into the pods it connects, the tube is hidden inside them, and the outlets are spaced, as they would be on a traditional power strip. When extended, the outlets could accommodate large plugs like power bricks. This would allow the strip to always be as small as possible while still making all of its outlets available. Other features that are less necessary, but are part of my dream concept, include the ability to rotate each outlet within its pod for further flexibility - rather than sliding a pod apart from its neighbor, a user might simply swing the offending power brick out of the way. Another idea is for the strip's own power plug to contain a spool for winding up its wide, flat cable, allowing the Usable Power Strip to further minimize its clutter. Also on the plug is the strip's power switch, which is a flush-mounted slider, so the strip cannot be accidentally shut off when kicking around under the desk. Finally, I've made the outlets smile. You know you've always wanted to see it happen. Enjoy, and please offer feedback! I've wanted to produce this 2006, so this is quite exciting.

Screenshots of Final Commercialized Product



Questionnaire

Please evaluate how much each design feature influence on product design with 0 to 10 scales.

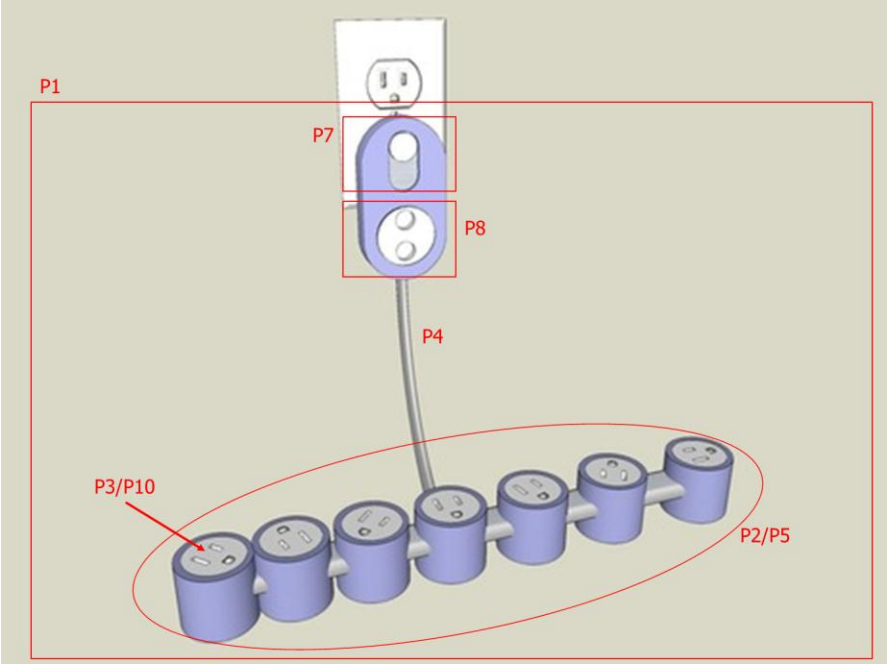
(0: No influence at all – 10: Full influence)

A. Part

In case of 'part', one or more part names can indicate actually the same part. Please ignore the redundancy and evaluate every question.

Type	**ID**	**Design Features**	**Description**	**Score (0-10)**
Part A (In case of descripted by initiator or drawn on initial image)	P1	Whole Product	Whole image of product design	
	P2	Power strip	Part of extension code excluding the portion of plugging into outlet	
	P3	Outlet	Area of a plug inserted into	
	P4	Wire	Cord of power strip	
	P5	Pod	Part which the outlets (P3) are gathered	
	P6	Power Switch	A switch which can turn on and off the power of outlets (P3) (This is now shown on the image but mentioned by idea initiator)	
	P7	Plug	Any power plug whether it comes from initiated idea or other product	
	P8	Spool	Part to wind cord of power strip	
Part B (In case of added on the list during discussion and collaboration)	P9	Surge Protector	Device or part to cut off electricity when over current is released	
	P10	Socket	Area of a plug inserted into (same as P3)	
	P11	Base unit	Base part to make outlets (or sockets) as a modular design	
	P12	Fuse	Fuse in surge Protector (P9)	
	P13	Circuit Breaker	Device or part which has both functions of surge protector (P9) and power switch (P6)	
	P14	Step-down	Device or part to adjust the difference of voltage (e.g. when	

		Converter	travel abroad)	
	P15	(Lightning) Indicator	Indicating light which shows the level of currency by colors	
	P16	Cover	Cover for each outlet (P3)	



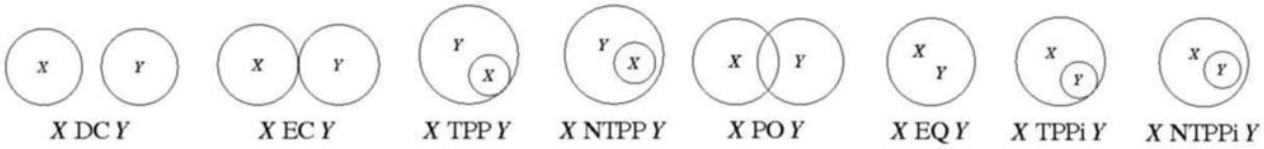
B. Structure

'Structure' is one of design factors that confirm how each part or component in section A is attached to whole product as a part or to other part each other. Please award scores on each question based on your perception whether such design factors are considered even if you cannot identify specific parts.

Type	**ID**	**Design Features**	**Description**	**Score (0-10)**
Structure	S1	DC (Disconnected)	Among part list (P1 ~P16), there exist at least two parts which are 'disconnected'	
	S2	EC (Externally Connected)	Among part list (P1 ~P16), there exist at least two parts which are 'Externally Connected'.	

	S3	EQ (Equal)	Among part list (P1 ~P16), there exist at least two parts which are 'Equal'.	
	S4	PO (Partially Overlapped)	Among part list (P1 ~P16), there exist at least two parts which are 'Partially Overlapped'.	
	S5/S6	TPP or TPPi (Tangentially Proper Positioned)	Among part list (P1 ~P16), there exist at least two parts which are 'Tangentially Proper Positioned'.	
	S7/S8	NTPP or NTPPi (Non-Tangentially Proper Positioned)	Among part list (P1 ~P16), there exist at least two parts which are 'Non-Tangentially Proper Positioned'.	

Remark: Refer the image below for your understanding about Structure



C. Function

The questions in this section are intended to confirm that the product or each part plays what kinds of functional roles with reflection of design information.

Type	**ID**	**Design Features**	**Description**	**Score (0-10)**
Function	F1	Object-f	N/A	*N/A*

	F2	Transformation-b	In functional perspective, one (or more) functionality has to be changed to other functionality since parts or products for such functionality do not meet the initial requirement in conceptual design. (e.g. The functional requirement such as 'The stationary-type socket should be changed to the swappable one' seems to be applied.)	
	F3	Prohibition-b	In functional perspective, one (or more) functionality has to be changed to other functionality in order to avoid a specific functionality to meet the objective of parts or products in conceptual design. (e.g. The functional requirement such as 'Cable - Not to be entangled' seems to be applied.)	
	F4	Process-f	In functional perspective, one (or more) functionality has to be changed to other functionality since parts or product for such functionality do not meet the initial requirement of performing specific procedures in conceptual design. (e.g. The functional requirement such as 'The functionality to swap a specific socket in serial order based on locations' seems to be applied.)	
	F5	Relation-f	In functional perspective, one (or more) functionality has to be changed to other functionality due to the importance of the specific relationship between parts or product for such functionality. (e.g. The requirement of relationship between two parts such as 'Tie together' seems to be applied.)	

D. Appearance

The questions in this section are intended to confirm how external design factors are reflected on the product.

Type	**ID**	**Design Features**	**Description**	**Score (0-10)**
Appearance	A11	Triangle	The information about the shape of '**Triangle**' is additionally reflected to specific part or whole design of the final product compared to initial conceptual design.	
	A12	Circle	The information about the shape of '**Circle**' is additionally reflected to specific part or whole design of the final product compared to initial conceptual design.	
	A13	Curve	The information about the shape of '**Curve**' is additionally reflected to specific part or whole design of the final product compared to initial conceptual design.	
	A14	Surface	The information about the shape of '**Surface**' is additionally reflected to specific part or whole design of the final product compared to initial conceptual design.	
	A15	Polygons	The information about the shape of '**Polygons**' is additionally reflected to specific part or whole design of the final product compared to initial conceptual design.	
	A2	Color	The information about the shape of '**Color**' is additionally reflected to specific part or whole design of the final product compared to initial conceptual design.	
	A31	Length	The information about the shape of '**Length**' is additionally reflected to specific part or whole design of	

			the final product compared to initial conceptual design.	
	A32	Width	The information about the shape of '**Width**' is additionally reflected to specific part or whole design of the final product compared to initial conceptual design.	
	A33	Height	The information about the shape of '**Height**' is additionally reflected to specific part or whole design of the final product compared to initial conceptual design.	

E. Environment

The questions in this section ask the designer's perception about the external environment of the provided product such as market situation or competitiveness of related technology.

Please assess each question below with your own perception.

Type	**ID**	**Design Features**	**Description**	**Score (0-10)**
Environment	E11	Complement	N/A	N/A
	E12 (E121, E122, E123)	Market Competition	There is the possibility of existence of same or similar conceptual design in the MARKET compared to the proposed conceptual design.	
	E21 (E211, E212, E213)	Technology	There is the possibility of existence of same or similar technology or patent compared to the proposed modular design.	

Remark

This questionnaire is developed based on a commercial product, Pivot Power, which is sold in a crowdsourcing service, Quirky.com.

Please refer the links below for further information.

Link 1: Commercialized Product https://www.quirky.com/shop/44

Link 2: Idea generation and Reponses https://www.quirky.com/invent/24238/action/vote/query/view=trending&categories=all

Thank you for your response!

APPENDIX B. Design Feature Data - Part

Participant ID	Part
U00	Power strip / outlet(s) / wire / pod(s) / tube / power switch / plug / spool
U01	NA
U02	NA
U03	Plugs
U04	NA
U05	NA
U06	Power strip
U07	Strip / Surge protector
U08	NA
U09	Cable management part (at the bottom of the strip) / (Little) runway
U10	Multi-tab / Sockets / Base unit
U10	NA
U10	Fuses / Circuit breakers
U10	Sockets / Cords
U10	NA
U11	NA
U12	USB outlets (one or two) / Flat connection point (to the wall)
U13	Outlets
U14	Brick type plugs
U15	NA
U15	Power plug
U16	NA
U17	Socket (Each having one socket on the upper side (the lid of the cube))
U18	Perpendicular line
U19	Plug
U20	NA
U20	NA
U21	NA
U22	NA
U22	NA
U23	Plug into the wall
U24	Outlets
U25	NA
U26	NA
U27	NA
U28	Multi-format (US/EU) sockets / Step-down converter

U28	NA
U28	NA
U28	NA
U28	NA
U29	NA
U30	Cover
U31	NA
U32	NA
U32	NA
U32	Whole product
U32	NA
U32	NA
U32	NA
U33	NA
U34	Lighting indicators
U35	Plug / Outlet
U36	Sockets / Plugs / On-Off Switch per socket
U37	NA
U38	NA
U39	Outlets
U39	NA
U39	Outlets / Cord
U40	Switch / Outlet
U41	NA
U42	NA
U43	NA
U44	NA
U44	NA
U45	NA
U46	Sockets
U47	LED
U47	Duplicate above
U47	NA
U47	NA
U47	NA
U48	NA
U49	Outlines
U50	Plug insertion point

APPENDIX C. Design Feature Data – Structure (Extracted)

Participant ID	Structure	DC	EC	EQ	PO	TPP	NTPP
U00	Yes	Yes	Yes		Yes	Yes	Yes
U01							
U02							
U03							
U04							
U05							
U06							
U07	Yes	Yes					
U08							
U09	Yes					Yes	
U10	Yes				Yes		Yes
U10							
U10			Yes				
U10	Yes		Yes				
U10							
U11							
U12	Yes						Yes
U13							
U14							
U15							
U15							
U16							
U17	Yes						Yes
U18							
U19							
U20							
U20							
U21							
U22							
U22							
U23							
U24							
U25							
U26							
U27							
U28	Yes	Yes					
U28							
U28							
U28							

U28							
U29							
U30							
U31							
U32							
U32							
U32							
U32							
U32							
U32							
U33							
U34							
U35	Yes	Yes					
U36	Yes						Yes
U37							
U38							
U39							
U39							
U39	Yes	Yes					
U40	Yes						Yes
U41							
U42							
U43							
U44							
U44							
U45							
U46							
U47							Yes
U47							
U47							
U47							
U47							
U48							
U49							
U50							

APPENDIX D. Design Feature Data – Function

	Function	Object-focused	Transformation-based	Prohibition-based	Process-focused	Relation-focused
U00	To be pushed up next to each other / To be pulled apart by a couple of inches / To connect each pair of neighboring pods / To slide in and out / To hide pods when collapsed / To accommodate large plugs when extended / To rotate each outlet within its pod / To wind its wide and flat cable / To minimize its clutter / Not to shut off accidently	Yes	Yes	Yes		Yes
U01	NA					
U02	NA					
U03	Multi type acceptable plug					Yes
U04	NA					
U05	NA					
U06	Not get anything else in the spots on either side	Yes		Yes		
U07	Bendable / To prevent from power surges	Yes	Yes	Yes		
U08	NA					
U09	Cable management function / To bend around all the extra cables / To tuck nice and neat	Yes	Yes			
U10	To grow or shrink the number of sockets / Socket attached to a base unit / Unused sockets are not usable without the base unit. / The individual sockets also do not pull apart to create needed space for wide ac adapters to plug into. / Each socket can be a base unit that you attach a cord / Gang sockets together / Plug sockets directly into a wall plug without a cord	Yes	Yes	Yes		
U10	NA					
U10	To draw excessive power / To prevent a fire danger	Yes	Yes	Yes		
U10	Individual socket can be used with a cord or grouped separately. / Usable without a cord / To hook cords together					Yes
U10	NA					
U11	Have better spacing between sockets	Yes	Yes			
U12	Pronged USB outlet	Yes	Yes			
U13	Power killing	Yes	Yes			
U14	Give enough space (= reduce space) / Swivel out of the way	Yes	Yes			
U15	NA					

U15	Not fit one or two on a regular power strip	Yes		Yes		
U16	NA					
U17	The possibility to join them side-by-side in all directions, on the lateral sides					Yes
U18	NA					
U19	To work behind furniture / To provide 'child proof'	Yes	Yes			
U20	NA					
U20	NA					
U21	NA					
U22	NA					
U22	NA					
U23	Not to get tangled	Yes		Yes		
U24	Rotatable to (better) accommodate different plug shapes or bricks	Yes	Yes			
U25	NA					
U26	NA					
U27	NA					
U28	NA					
U28	NA					
U28	NA					
U28	NA					
U28	NA					
U29	NA					
U30	Covers for outlets / Read amperage					
U31	NA					
U32	NA					
U32	NA					
U32	Use under a desk	Yes	Yes			
U32	NA					
U32	NA					
U32	NA					
U33	NA					
U34	To support different footprints / Connect to the outlets / Color indication / Keep people energy conscious	Yes	Yes			Yes
U35	Protect surge / Save space	Yes	Yes			
U36	Exchangeable sockets / Available various plugs / Save power	Yes	Yes		Yes	
U37	Rotation ability / Surge protection					
U38	NA					
U39	Use all the outlets	Yes	Yes			
U39	NA					
U39	NA					
U40	Save energy / On-off function	Yes	Yes			

U41	NA					
U42	NA					
U43	NA					
U44	NA					
U44	NA					
U45	NA					
U46	Not to blow / trip the fuse	Yes		Yes		
U47	Show flow of current / Help in identifying the defect in case of failure	Yes	Yes			
U47	Duplicate above					
U47	NA					
U47	NA					
U47	NA					
U48	NA					
U49	Illuminate	Yes	Yes			
U50	Easy to plug	Yes	Yes			

APPENDIX E. Design Feature Data – Appearance

Participant ID	Appearance	Shape	Triangle	Circle	Curve	Surface	Polygons	Color	Size	Length	Width	Height
U00	Cylindrical (pod) / As small as possible / Wide and flat (cable) / Flush-mounted (slider)			Yes					Yes	Yes	Yes	Yes
U01	NA											
U02	NA											
U03	NA											
U04	NA											
U05	NA											
U06	Too wide								Yes		Yes	
U07	NA											
U08	Modular idea / Add a unit for a brick	Yes				Yes						
U09	NA											
U10	NA											
U10	NA											
U10	NA											
U10	Modular design / Different lengths of strips / Mix and match design								Yes	Yes		
U10	NA											
U11	Flush to the wall								Yes			Yes
U12	One or two USB outlets / 3-pronged USB Outlet / Not big, Not bulky	Yes				Yes			Yes	Yes	Yes	Yes
U13	Green trends(?) - light							Yes				
U14	NA											
U15	NA											
U15	Not block type											
U16	NA											
U17	Cubical shape / The possibility to join them side-by-side in all directions, on the lateral sides	Yes					Yes		Yes			Yes
U18	NA											
U19	Flat plug / Child-proof	Yes				Yes			Yes			Yes
U20	NA											

U20	NA											
U21	NA											
U22	Not circular design	Yes		Yes								
U22	NA											
U23	Flush / Slim design								Yes	Yes	Yes	Yes
U24	NA											
U25	NA											
U26	NA											
U27	NA											
U28	Modular design / Not too complex / Not bigger / Not much pretty	Yes				Yes			Yes	Yes	Yes	Yes
U28	NA											
U28	NA											
U28	NA											
U28	Not circular design / Not angled design	Yes	Yes	Yes			Yes					
U29	NA											
U30	NA											
U31	NA											
U32	NA											
U32	NA											
U32	Not circular type design	Yes		Yes								
U32	No squid type / Balance and rest comfortably under a desk											
U32	NA											
U32	NA											
U33	NA											
U34	Flexible											
U35	NA											
U36	NA											
U37	NA											
U38	NA											
U39	Too small								Yes	Yes	Yes	Yes
U39	NA											
U39	Too small / Too many outlets / Too close each outlet / Extend the length of the cord								Yes	Yes		
U40	NA											
U41	NA											

U42	NA											
U43	NA											
U44	NA											
U44	Sleek design	Yes				Yes						
U45	NA											
U46	(Limit) the number of sockets								Yes	Yes		
U47	NA											
U47	Duplicate above											
U47	NA											
U47	NA											
U47	NA											
U48	NA											
U49	NA											
U50	white; not black							Yes				

APPENDIX F. Design Feature Data – Environment

Participant ID	Environment	Market	Complement	Competition	Technology	Patent	IP
U00	Similar products on market	Yes		Low			
U01	NA						
U02	Compliment		Yes				
U03	NA						
U04	Compliment	Yes	Yes				
U05	Compliment	Yes	Yes				
U06	Compliment	Yes	Yes				
U07	NA						
U08	NA						
U09	NA						
U10	No patent concern				Low		
U10	Patent concerns				High	Yes	
U10	NA						
U10	Packaging idea						
U10	Already exist	Yes		High			
U11	NA						
U12	NA						
U13	NA						
U14	Compliment	Yes	Yes				
U15	Compliment	Yes	Yes				
U15	Negative response	Yes	No				
U16	Compliment		Yes				
U17	NA						
U18	NA						
U19	NA						
U20	Compliment	Yes	Yes				
U20	Compliment	Yes	Yes				
U21	NA						
U22	Not on the market	Yes		Low			
U22	Compliment	Yes	Yes				
U23	Compliment	Yes	Yes				
U24	NA						
U25	Compliment	Yes	Yes				
U26	Compliment		Yes				
U27	Patent concern				High	Yes	
U28	Not expensive			High			
U28	Patent concerns				High	Yes	
U28	Risk on modular design / Connect too many outlets			High	High		
U28	'Willingness-to-Pay' concern	Yes		Mid			
U28	Circular design and angled design on the market	Yes		High			
U29	Similar products on market	Yes		High			
U30	NA						
U31	Compliment / As cheap as possible	Yes	Yes	High			
U32	NA						
U32	NA						
U32	Comparison with similar products	Yes		High			
U32	NA						

U32	NA						
U32	NA						
U33	Compliment	Yes	Yes				
U34	NA						
U35	Compliment	Yes	Yes				
U36	NA						
U37	Compliment		Yes				
U38	Compliment		Yes				
U39	NA						
U39	NA						
U39	NA						
U40	NA						
U41	NA						
U42	Compliment		Yes				
U43	NA						
U44	Compliment		Yes				
U44	NA						
U45	NA						
U46	NA						
U47	NA						
U47	Duplicate above						
U47	Compliment		Yes				
U47	NA						
U47	NA						
U48	Compliment		Yes				
U49	NA						
U50	NA						

APPENDIX G. Design Feature Data - Participant (user)

user_id	commentable_id	commentable_type	created_at	user/id	user/created_at	user/earnings_data/cents	user/follower_count	user/skills
26599	24238	Ideation	2010-04-26T23:44:11-04:00	26599	2010-04-27T12:04:39-04:00	67629714	3540	
67	24238	Ideation	2010-04-29T22:11:10-04:00	67	2009-05-19T19:46:00-04:00	882021	1434	Branding,Design,Manufacturing
3593	24238	Ideation	2010-05-03T04:52:22-04:00	3593	2009-09-02T01:48:49-04:00	922393	87	Fashion,Research,Investments
3637	24238	Ideation	2010-04-30T01:06:30-04:00	3637	2009-09-03T21:53:35-04:00	189931	162	Time Savers,Gadgets,Tweaking.
3986	24238	Ideation	2010-04-27T21:42:02-04:00	3986	2009-09-06T21:42:10-04:00	1186294	2366	Foodie,Children
5169	24238	Ideation	2010-04-27T18:05:42-04:00	5169	2009-09-11T15:39:22-04:00	279941	51	
6390	24238	Ideation	2010-04-29T00:41:51-04:00	6390	2009-09-15T22:24:43-04:00	103655	9	
8467	24238	Ideation	2010-04-29T09:24:14-04:00	8467	2009-10-29T08:40:46-04:00	501351	177	Thinking
9274	24238	Ideation	2010-04-29T13:27:30-04:00	9274	2009-11-09T16:40:31-05:00	28825	119	
9636	24238	Ideation	2010-04-29T10:25:09-04:00	9636	2009-11-13T10:42:27-05:00	2347166	2246	Mechanical Engineer,Information Technology
10440	24238	Ideation	2010-04-30T13:25:28-04:00	10440	2009-11-25T18:38:31-05:00	2468917	2081	Consumer Product Development
10440	24238	Ideation	2010-04-29T19:21:09-04:00	10440	2009-11-25T18:38:31-05:00	2468917	2081	Consumer Product Development
10440	24238	Ideation	2010-04-29T16:05:30-04:00	10440	2009-11-25T18:38:31-05:00	2468917	2081	Consumer Product Development

10440	24238	Ideation	2010-04-29T12:33:08-04:00	10440	2009-11-25T18:38:31-05:00	2468917	2081	Consumer Product Development
10440	24238	Ideation	2010-04-29T12:32:37-04:00	10440	2009-11-25T18:38:31-05:00	2468917	2081	Consumer Product Development
10784	24238	Ideation	2010-04-27T22:18:57-04:00	10784	2009-11-28T21:02:50-05:00	1359022	107	Art Direction,Graphic Design,Web Design And Development,User Interface Design,User Experience Specialist,Marketing,Technology,Basketball
11905	24238	Ideation	2010-05-01T10:54:48-04:00	11905	2009-12-08T11:01:07-05:00	217691	55	
13304	24238	Ideation	2010-04-29T22:18:10-04:00	13304	2009-12-28T16:22:26-05:00	427317	693	Psychology,Creative Endeavors,Tinkering,Fixing Things,Brainstorming,Ideation
13985	24238	Ideation	2010-04-27T22:24:22-04:00	13985	2010-01-02T17:21:02-05:00	105872	540	Graphic Design,Game Design,Computer Software,Computer Hardware
15360	24238	Ideation	2010-04-27T15:36:28-04:00	15360	2010-01-26T11:03:09-05:00	619390	370	I.T. Technician,Web Designer,Business,Marketing,Sales,Internet Technology
15360	24238	Ideation	2010-04-27T15:04:03-04:00	15360	2010-01-26T11:03:09-05:00	619390	370	I.T. Technician,Web Designer,Business,Marketing,Sales,Internet Technology
15511	24238	Ideation	2010-05-03T10:30:55-04:00	15511	2010-01-28T19:18:57-05:00	0	278	Communityambassador,Admin,Support,Education,Communication
15926	24238	Ideation	2010-04-30T09:08:54-04:00	15926	2010-02-04T09:51:07-05:00	272991	406	Utilities,Organizers,Space Optimization,Automated Processes
16810	24238	Ideation	2010-04-29T14:38:48-04:00	16810	2010-02-18T16:15:19-05:00	2920267	1300	Invention,Problem Solving,Fly Fishing
22143	24238	Ideation	2010-04-29T14:11:29-04:00	22143	2010-03-12T15:35:54-05:00	127464	465	Artist,Designer,Geek
22516	24238	Ideation	2010-04-27T16:00:08-04:00	22516	2010-03-17T13:27:50-04:00	2203207	2978	Dreamer
22516	43475	Comment	2010-04-27T16:01:26-04:00	22516	2010-03-17T13:27:50-04:00	2203207	2978	Dreamer
22637	24238	Ideation	2010-04-27T18:38:3	22637	2010-03-18T16:02:2	10533907	1843	Technology,3 D Design,Coding,Hacking

			1-04:00		3-04:00			
23515	24238	Ideation	2010-04-27T22:53:34-04:00	23515	2010-03-31T16:56:59-04:00	173253	466	Computer Programming,Statistics
23515	24238	Ideation	2010-04-27T19:00:48-04:00	23515	2010-03-31T16:56:59-04:00	173253	466	Computer Programming,Statistics
23657	24238	Ideation	2010-04-28T10:13:12-04:00	23657	2010-04-03T12:29:27-04:00	146828	98	Writing,Taxiing Kids Around (My Specialty)
24003	24238	Ideation	2010-04-29T12:12:07-04:00	24003	2010-04-06T12:19:11-04:00	139489	32	Music,Art,Science,Cooking,End User Perspectives,Applying Existing Ideas In New Ways,Eco Friendliness,Being Green (It Ain't Easy)
24058	24238	Ideation	2010-04-28T20:18:06-04:00	24058	2010-04-06T16:41:06-04:00	333901	214	
24988	24238	Ideation	2010-05-01T22:27:20-04:00	24988	2010-04-12T17:11:03-04:00	1426351	1066	Publishing,Advertising,Illustration,Graphic Design,Art Direction,Piano,Banjo Pickin,Thumb Wrestling
25899	24238	Ideation	2010-04-30T10:41:42-04:00	25899	2010-04-20T20:11:35-04:00	0	4	I Have A Knack For Identifying Minor Tweaks In Products That Make The Ordinary Exceptional
25906	24238	Ideation	2010-04-30T14:25:05-04:00	25906	2010-04-20T21:14:00-04:00	0	4	Music,Art,Photography
25906	24238	Ideation	2010-04-29T16:55:45-04:00	25906	2010-04-20T21:14:00-04:00	0	4	Music,Art,Photography
25906	24238	Ideation	2010-04-29T14:46:42-04:00	25906	2010-04-20T21:14:00-04:00	0	4	Music,Art,Photography
25906	24238	Ideation	2010-04-29T14:43:26-04:00	25906	2010-04-20T21:14:00-04:00	0	4	Music,Art,Photography
25906	24238	Ideation	2010-04-27T22:32:42-04:00	25906	2010-04-20T21:14:00-04:00	0	4	Music,Art,Photography
25966	24238	Ideation	2010-04-28T00:00:14-04:00	25966	2010-04-21T15:19:38-04:00	689712	2252	Web Development,Graphic Design,Design,Technology,Business,Entrepreneurship,Sales,Marketing,Branding,Finance,Electronics,Cooking,Martial Arts,Photography,Music,Art,Computer

26429	24238	Ideation	2010-05-03T03:13:08-04:00	26429	2010-04-26T18:13:21-04:00	0	4	Im A Emergency Medical Personnel,Paint,Martial Arts,Think Of Crazy Inventions And Ideas.
26550	24238	Ideation	2010-04-28T08:32:54-04:00	26550	2010-04-27T10:41:22-04:00	107401	16	
26599	24238	Ideation	2010-04-30T13:44:11-04:00	26599	2010-04-27T12:04:39-04:00	67629714	3540	
26599	43676	Comment	2010-04-28T09:06:52-04:00	26599	2010-04-27T12:04:39-04:00	67629714	3540	
26599	43649	Comment	2010-04-27T22:58:02-04:00	26599	2010-04-27T12:04:39-04:00	67629714	3540	
26599	24238	Ideation	2010-04-27T21:50:26-04:00	26599	2010-04-27T12:04:39-04:00	67629714	3540	
26599	43545	Comment	2010-04-28T09:05:38-04:00	26599	2010-04-27T12:04:39-04:00	67629714	3540	
26599	24238	Ideation	2010-04-27T15:32:34-04:00	26599	2010-04-27T12:04:39-04:00	67629714	3540	
26666	24238	Ideation	2010-04-27T15:21:58-04:00	26666	2010-04-27T13:45:43-04:00	117233	3	Web And Graphic Design,Music,Woodworking
27030	24238	Ideation	2010-04-28T23:17:15-04:00	27030	2010-04-28T22:50:30-04:00	125706	14	Computers,Gadgets,Tools,Electronics
27038	24238	Ideation	2010-04-29T01:24:02-04:00	27038	2010-04-29T00:59:33-04:00	103374	4	
27172	24238	Ideation	2010-04-30T02:07:33-04:00	27172	2010-04-30T01:53:01-04:00	103374	4	
27313	24238	Ideation	2010-05-01T15:57:12-04:00	27313	2010-05-01T15:42:26-04:00	0	4	
172937	24238	Ideation	2013-02-22T23:05:32-05:00	172937	2012-01-18T00:38:48-05:00	111140	1374	Inventor,Artist,Writer
210001	24238	Ideation	2013-03-01T15:21:45-05:00	210001	2012-04-08T12:32:22-04:00	23344	1486	

210001	24238	Ideation	2013-02-22T20:07:25-05:00	210001	2012-04-08T12:32:22-04:00	23344	1486	
210001	24238	Ideation	2013-02-22T20:05:32-05:00	210001	2012-04-08T12:32:22-04:00	23344	1486	
235969	24238	Ideation	2013-03-05T12:43:17-05:00	235969	2012-06-10T02:43:02-04:00	1524	193	
250548	24238	Ideation	2013-02-20T21:07:38-05:00	250548	2012-07-17T16:01:02-04:00	17927	1694	
256337	24238	Ideation	2013-02-21T19:25:52-05:00	256337	2012-08-05T16:00:42-04:00	1151	317	
306697	24238	Ideation	2013-05-07T10:43:10-04:00	306697	2012-11-02T02:23:36-04:00	821	621	
324796	24238	Ideation	2013-05-22T19:29:51-04:00	324796	2012-12-02T23:34:06-05:00	7117	1769	Investing,Sales And Marketing
324796	43742	Comment	2013-05-22T18:06:09-04:00	324796	2012-12-02T23:34:06-05:00	7117	1769	Investing,Sales And Marketing
326358	24238	Ideation	2013-03-02T18:03:05-05:00	326358	2012-12-04T22:02:20-05:00	645	182	
379778	44026	Comment	2013-02-22T08:02:46-05:00	379778	2013-02-22T07:37:31-05:00	0	1	
404741	24238	Ideation	2013-04-08T06:13:36-04:00	404741	2013-03-28T03:37:41-04:00	3962	112	
404741	24238	Ideation	2013-04-05T08:46:08-04:00	404741	2013-03-28T03:37:41-04:00	3962	112	
404741	1553459	Comment	2013-09-14T03:24:54-04:00	437618	2013-05-23T03:49:09-04:00	3962	112	
404741	1895005	Comment	2013-09-14T03:25:06-04:00	437618	2013-05-23T03:49:09-04:00	3962	112	
404741	1895006	Comment	2013-09-14T03:25:12-04:00	437618	2013-05-23T03:49:09-04:00	3962	112	

442637	24238	Ideation	2013-06-06T00:42:59-04:00	442637	2013-06-01T19:33:35-04:00	8099	526	
478552	2368531	Comment	2013-12-06T12:28:27-05:00	478552	2013-08-05T13:07:52-04:00	7014	1915	
536855	24238	Ideation	2013-11-23T17:56:59-05:00	536855	2013-09-19T19:34:25-04:00	5536	398	Theatrical Design,Technical Direction,Drafting

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ABSTRACT

FORMAL DESIGN CONCEPT AND PARTICIPANT BEHAVIOR ANALYSIS FOR CROWDSOURCING DESIGN

by

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May 2015

Advisor: Kyoung-Yun Kim, Ph. D

Major: Industrial Engineering

Degree: Doctor of Philosophy

Crowdsourcing has emerged as a new design resource for conceptual design process and multiple crowdsourcing services provide an opportunity for design idea collection and concept generation by crowds. However, few formal methods are available to extract and evaluate design concepts from the activities of the design crowd. Scarcity of information and non-guaranteed quality of contributions are often challenges to be tackled. To overcome the challenges, the research aims to answer how a system systematically extracts and represents the explicit or implicit hidden design concepts from crowdsourcing design activities and how crowdsourcing design activities of participants are captured as design information to develop a product in crowdsourcing platform in the perspectives of process and elements.

This research provides taxonomy of design features to represent crowdsourcing design activities. With the taxonomy, a formal concept analysis method, Galois lattices, is applied to

evaluate activities of design crowd and to extract possible design concepts. Using this approach, the crowd activities are represented with design features and participant information and it allows modeling the potential design concepts with the contributions of participants. Two participant evaluating measures, *Participant Individual Score* and *Participant Group Score,* are proposed to enhance the extracted design concepts with participants' information. By employing the proposed scores and design features, this research figure out the significance of participants' behavior in crowdsourcing design. In addition, a formal method to represent the processes and elements in crowdsourcing design activities with the theory adopted from social science, Actor Network Theory. The presented method and metrics are validated with a real design data collected from a crowdsourcing service by focus group interview and precision and recall tests.

AUTOBIOGRAPHICAL STATEMENT

I was born in Pusan, Republic of Korea, in 1975. I received my bachelor's degrees from the School of Management and Economics at Handong Global University in 2003 and my master degree from the Department of International Management at Kyung Hee University in 2006. During my master's work, I focused on developing methodologies for ubiquitous computing services by applying SERVQUAL approach to detect the potential service quality which the service is not yet realized. During my doctoral study in the Department of Industrial and Systems Engineering at Wayne State University, I have gained a broad range of interests spanning from computational intelligence, semantics, and user behavior analysis, for the design engineering, proposed a new design concept analysis method for crowdsourcing design and developed formalisms for crowdsourcing design supporting participants. Throughout these diverse experiences, I have pursued a consistent goal of applying data science and behavioral analysis of users to support innovative product designs. To accomplish this goal, I have focused on conceptual design in crowdsourcing as the fundamental aspect of product designs. My approach to research focuses on enhancing conceptual product design and understanding user behavior in crowdsourcing design.