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A Study on Creation of Human-Based Co-Design Service Platform

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***Abstract*—**With the approaching of digital era, various interactive service platforms and systems support human beings' needs in lives by different contents and measures. Design strategies have gradually turned from function-based to user-oriented, and are often customized. In other words, how designers include users' value reaction in creation becomes the goal. Creative design service of interior design requires positive interaction and communication to allow users to obtain full design information, recognize the style and process of personal needs, develop creative service design, lower communication time and cost and satisfy users' sense of achievement. Thus, by constructing a co-design method, based on the communication between interior designers and users, this study recognizes users' real needs and provides the measure of co-design for designers and users.

***Keywords*—**Co-Design, Customized, Design Service, Interactive Genetic Algorithm, Interior Design.

I. Background and Objective

IN 1988, Hasell [9], an American interior designer, gave the following definition for interior design: "To give innovative presentation in the interior space of a building, from the perspectives of society, aesthetics and environment, and based on cultural, physiological, psychological, economical, historical and behavioral preferences of an individual or a group of people, by utilizing natural and manmade elements." The New Encyclopedia Britannica 1974 defines Interior Design as: "Interior Design is a specialized branch of architectural or environmental designs; it is a problem solving activity featuring innovation." In other words, Interior Design is an activity that combines elements such as environment, culture, interpersonal interaction and communication, and individual style and taste, thus leading to innovation; it integrates elements such as life, psychology, and sight; it is also a symbol of aesthetics.

In the process of traditional interior design, a designer converts to a concrete form the concept generated from the ideas and needs dictated by a user (client), by using his/her professional knowledge and drawing tool. The final product is generated through iterations of communication and modification, which is thus a time consuming process. Although this process can be accelerated with the help of software today, discussions are still required to confirm with the user repeatedly. Besides, in an innovative design service of interior design, innovation must take into consideration user's needs and the consensus with such needs can be met only when the designer makes suggestions as an expert from the side. On the other hand, interior design requires good interaction and communication to allow the user to access sufficient information related to design, thus allowing him/her to understand the style elements of his/her own needs and generating innovative service design jointly. The time and the cost of communication can thus be reduced, and the user may feel the sense of achievement. Therefore, the issue of how to create a platform mechanism for design service which can display the process of communication is worth of investigation, and is an area to be developed and researched.

On the other hand, service science is gradually receiving attention due to the development of information technology, vital functions of life, and the trend of service economy in global industry. Special consumer experiences continue to evolve from Internet and new market mechanisms emerge as well. The digital network gives individual great flexibility in decision making, thus affecting life attitude and consumption pattern. In this environment where the needs of an individual are valued, the need for customization in the service industry is receiving attention and changing the supply relationship in traditional industry. With the increase of customized orders, traditional idea of mass production of the same type of product is losing its edge. Instead, the idea of how to satisfy various needs of the customers is on the rise. Flexibility is now the trend in service offer. Integration of network and production mechanism by taking advantage of real time connection with the user and the feature of sharing offered by the network is an important part in production workflow. Networking and digitalization enable an open platform, thus re-establishing the role of the user and the interactive relationship. In other words, digitalization provides an opportunity to contact the user and achieve the best capacity through a platform. The platform is therefore not merely the tool used for one single design work.

Because of these reasons, it is necessary to reconsider the relationship between interior design and the digital environment. The user may participate in the design process and create his/her own experience of aesthetics through Internet which serves as a platform for communication between users and designers. Thus, summarizing above-mentioned perspectives, a framework for joint creation of design service is proposed to allow the user to participate in the creation of service and to obtain optimized services through a co-design and thinking process when the service is being provided. The framework and methodology of the human-based co-design service platform (as shown in Fig. 1 Framework of Theory) include discussions in three aspects, namely co-design innovation value, customization of interior service design, and the optimization of interactive genetic algorithm. The user's design needs are met through the method of co-design

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evolution. The concepts of design-thinking, co-design and evolution are used to allow the user to obtain service solution based on customized design suggestions through interactive genetic algorithm in the process of design.

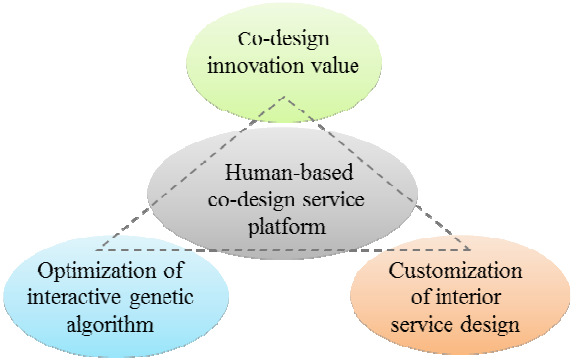

Fig. 1 Theoretical framework of the human-based co-design service platform

II. Related Studies

Different subjects in the important studies are further explained by following the objective of this study. Detailed evaluations are as follows:

A. Co-Design and Service Design

The co-design concept proposed by Binder et al. [3] generally refers to sharing of experience among various experts, such as designers, companies, researchers, users and potential users etc., and to the joint exploration of potential solutions addressing certain problems. Overall speaking [31], experts of different fields participating in co-design help generate new values for service design concept, service providers and service receivers. In the aspect of service design concept, it means more innovations, better service design concept, and improved design performance; in the aspect of service receiver, better compliance with needs, better service experience and improved service satisfaction; and in the aspect of service provider, more creativity, more interdisciplinary cooperation, and innovation. To fill the service gap, users are invited to participate in activities such as proposing idea for service experience, solving certain problem together, co-designing visible or invisible objects, or participating in mutually beneficial discussions. Traditional design process typically requires questionnaire, interview, and observation on users from problem identification to problem definition. In the development of new and future design object tacit knowledge and latent needs may not be discovered because tacit knowledge is the knowledge that can be acted upon, but cannot be easily expressed through language, while latent needs are needs which people are not yet aware of, but hope to realize in the future. Such a traditional method of surveying user needs often has its limit. From a design perspective, the messages acquired include only experiences from the past and present, but lack visions for the future. This is where co-design comes into play: the researcher provides the tool for designers and users to express their own experiences and ideas [25].

Furthermore, traditional design process places emphasis on design object itself. As user-centered concept gains popularity in recent years, more and more design methods have improved design quality by understanding the user [30]. This trend also impacts the design process of traditional service platform-designers communicate with users by utilizing co-design technology and tool, thus allowing more effective design ideas and creating more opportunities for service innovations [24] [36].Sanders et al. [26] pointed out that experiences involved in design should include those of the past, the present, and the future, while experiences should be divided into three aspects: memory, moment, and dream. Also as a result of this, designers can collect current ideas and feelings, and dreams for the future on design object through generative methods. In other words, designers need more messages that influence the experience of interaction between users and design objects to design a design object that complies with users' experience and meets their expectation. By combining these massages with designers' expertise and knowledge, user experiences and needs are further explored and introduced to design process. Designers may then be inspired by new design concepts in the early stage of design and avoid being caught in presuppositions [28].

On the other hand, the concept of service design has its origin in marketing management, but has become an independent subject since 1990 with the changes of market in recent years [29].According to Mager [21], service design is an emerging discipline that is growing rapidly and covers a wide and diverse area. It also combines studies of different disciplines, such as social sciences, information management and interactive design. Holmlid and Evenson [12] pointed out that service design, according to its definition, includes methods and views of human based service development. They stress that service design refers to a complete experience design with focuses on service touch-points between users and companies, thus exploring potential opportunity points and developing innovative services. In addition, the web site of Service Design [27] also mentions that service design features the following 4 characteristics:

1) It is generally referred to as a system.
2) It can explore user needs by using creativity and thinking like-mindedly.
3) It builds a user-based service solution on the basis of being usable, useful, efficient, effective, and desirable.
4) Innovation service must be feasible, viable and valuable from the perspective of a producer.

Furthermore, Stickdorn and Schneider [32] pointed out that service design must feature five principles as follows:

1) It is user-based- Service design should be performed based on customer's perspective.
2) It is collaborative- All stakeholders must be considered in the process of service design.
3) It is progressive- Service should provide visibility and correlation.
4) It is content oriented- Invisible services must be built upon

visible service content.

5) It is integrated- The environment of tangible service must be considered as a whole.

In recent years, service design has played a very important role in the development of business models and public services. The UK Design Council [34] has stressed three advantages of including service design:

1) Allows public service to truly satisfy customers.
2) Reduces unnecessary expenses of the public sector with design testing.
3) Provides real benefits, such as improved service efficiency, from innovative service models. Therefore, service design is an important tool for public service innovation and helps produce satisfactory services between users and companies.

We can see that service design emphasizes cooperation among groups of different disciplines. It conducts comprehensive assessments on user needs and service field and produces benefits for both companies and users. By summarizing and referencing the views above, it is concluded that traditional design process is changing from user-based design to co-design and the role of the user is increasing in importance. In a traditional user-based study, the user was passively involved in the process while researcher formed the theory with the knowledge acquired from observations and interviews. The designer received the report passively and finally came up with design ideas by employing his/her own creative thinking and understanding of knowledge technology.

Therefore, in order to ensure that the content of design meets the needs of daily life and inspires designer's idea, user must be guided in the process to express the knowledge deep in his/her mind. The user and relevant professional both participate in the design process and explore the world deep inside of the user to design objects more suitable for the user. A better experience base may therefore be built and used as method of development for subsequent design.

B. Genetic Algorithm, Interactive Genetic Algorithm, and Human Based Genetic Algorithm

The fundamental theory of Genetic Algorithm (GA) was first proposed by Holland [11] in 1975. Its basic principle is derived from Darwin's theory of "Natural selection and survival of the fittest."GA is a simulation of competition and survival among living creature in the natural world. A question parameter is encoded as a chromosome, representing a point in the solution space. The best solution is searched out in the solution space using multiple groups of chromosomes. In the process of evolution, selection, crossover, and mutation algorithms are carried out through iterations to exchange information of the chromosomes in the group and create new generations. This process of evolution and alternation will continue until final conditions are met. The advantage of traditional GA in problem solving lies in its ability to find the most suitable solution from an enormous problem space [7]. The evaluation of some problems, however, involves not only objective factors, such as cost, time etc, but also human's subjective evaluation, such as the most favorite and the most beautiful things, etc. Objective factors are factors of quantitative assessment, which can be easily quantified; but subjective factors are factors of qualitative assessment, which cannot be easily quantified. It is also difficult to define a function as the fitness function of GA. The much discussed Interactive Genetic Algorithm (IGA) in recent years was developed to address such a problem.

However, the improvement of traditional IGA was only made in the area of fitness assignment method, thus often leading to human fatigue; therefore, Kosorukoff [17] proposed a self-learning framework: Human Based Genetic Algorithm (HBGA). This framework allows the user to optimize the order of evaluation through online ratings and user fitness function, thus keeping subjective factors and knowledge deep in the evolutionary process. Moreover, HBGA is a multi-agent environment in which the coordinator communicates among multiple agents of the same nature. The advantages of HBGA are: addressing complicated problem and allowing people to participate evolutionary process of the system in the roles of evaluator or innovator. In other words, HBGA may be considered as an improved IGA. In IGA only human's rating is used while in HBGA human is not only an evaluator, but also an innovator. That is to say, human not only gives fitness function, but also performs the operations of mating and mutation. Therefore, HBGA encourages the use of human judgment and creativity of potential participants in presentation and even uses agents of algorithm to balance the entire evolutionary process. The framework of HBGA develops a fitness system combining the features of both GA Global Search Ability and Human Ability of Evaluation, enabling a solution to the problem with difficulty in developing fitness function and widening the application field.

In 2001, Takagi [33] concluded that there had been two major directions in the study of IGA in recent decade by comparing 252 papers related to IGA: (1) Application study – 208 papers in 20 categories; (2) Non-application study– 44 papers in 6 categories. He also pointed out that the major problem addressed in the application study of IGA was how to reduce human fatigue. The reason why IGA has caused human fatigue is that human intervention is required in evaluating fitness value of chromosomes in each generation of evolution. Though IGA system has strict limitation to population size and the number of generations, i.e. less than 20 generations and 10 populations, it is indeed a heavy burden for a user to rate tens of or even hundreds of chromosomes. In traditional IGA intervention evolution method, human's subjective evaluation is used in lieu of GA fitness function. However, communication with human agent is completed through interactive interface in new HBGA. Just like IGA in which human is used in lieu of fitness function of GA, new HBGA also allows human interventions in the operations of selection, mating, and mutation in GA. From the comparison made among GA, IGA and HBGA, and from the angle of "evolution process to evolution operation" alone (as shown in Table I), a clear picture depicting a process from "a fully-computerized evolution" to "a fully human-operated evolution" can thus be seen. The evolution process of GA is

totally covered by the computer. In IGA all the process is also covered by the computer except for the selection which is done by human. HBGA thus covers IGA and all possible combinations of human operations [18].

TABLE I
COMPARISON OF GA, IGA WITH HBGA

Algorithms	Selection	Crossover	Mutation	Fitness function
GA	Computer	Computer	Computer	Computer
IGA	Human	Computer	Computer	Human
HBGA	Human	Computer/ Human	Computer/ Human	Computer/ Human

However, according to the study [19], [20], the fitness function in the mind of IGA users often varies with time, inevitably leading to lower performance of IGA-based evolution and thus human fatigue. Hence, how to reduce instability of the fitness function has become another important issue in solving the problems of fatigue. Babbar et al. [1] have discovered that there is a dramatic improvement in the quality of the design products from experts' usage of IGA, and have emphasized that using IGA-based tool requires interaction with the experts. This indicates that IGA-based tool gives more flexibility in solving the problems while it is less affected by the mechanism of evolution. In summary, the result of IGA experiment shows the chromosomes of the Initial Population are closer to the objective of evolution, thus yielding better evolutionary performance. This study shows that there is a positive impact to the satisfaction with the result of IGA-based evolution if users can indicate beforehand information about their preferences or things they like as the basis for generating Initial Population. However, even so, there is still no mentioning of the issues with and the feasibility of human intervention in the generation of Initial Population under the definition of HBGA. Is it mandatory for the procedure of evolution to be consistent with that of computation if human intervention is introduced into all computations of evolution? This is an issue worth of discussion.

On the other hand, according to 252 papers (as shown in Table II) in the field of Interactive Evolutionary Computation, compiled and classified by Takagi [33] from 1980s to 2000, it is shown that GA Evolutionary method has been employed in many fields, including design, art, computer graphics, knowledge base, data mining, 3D animation, Internet, games, social education, medical services, etc. However, there are still very rare projects and literature which explore the subject of optimum design in the field of interior design by utilizing HBGA. Therefore, HBGA will be employed as the major method for evolutionary computation of co-design once the follow-on platform is developed under this study. HBGA is chosen because it features broad search area for answers and can deliver presentation directly in an interactive interface graphic design, unlike GA and IGA, which find user preferences or things users like through a questionnaire.

C. Recent IGA-Based Applications in the Field of Design

In the field of design, recent IGA-based applications include Graphic Design [37], Interactive Interface Design [23], Product Design [2], [20], Fashion Design [22], Interior Design [10], [38], and a series of IGB-based design for ergonomic furniture and chairs by Brintrup et al. [4], [5].Color design is the best strategy in creating attractive product economically and effectively, especially in the field of interior design. It is important to know how to create massive and diversified color plans for target population in the initial stage of design. These color plans can help designers find some good color schemes, and color combination can have strong influence on how customers feel. Huang et al. [13], [14], [15], [16] developed a color plan consulting and simulating system based on above concept to help designers produce optimum colors for components and decorative patterns. Such a system consists of two sub-systems: (1) an innovative evolutionary system which is created by using Interactive Genetic Algorithm and can interact with designers to obtain innovative design proposal; (2) a color simulation system which is created by using Extended Area Extraction Algorithm, and can simulate color plan on components and decorative patterns and verify the feasibility of system execution by using design case. Fukada et al. [6] also created a strategy support system for interior spatial design on the basis of IGA and used it to evaluate and simulate the color schemes of walls, windows, carpet, floor lamp, sofa, and cushions.

Gong et al. [8] employed IGA in the field of fashion design, further proving the powerful search ability of IGA, which enables users to find preferred dress from plenty choices of answers and helps non-professional designers design their dress effectively. This study points out that excessive rating scales may bring burden to the user during rating. Generally speaking, users can rate on a scale of 5 with ease, but they may have difficulty with one of 7 or more, in which case they will be perplexed when trying to figure out the minute differences between scales due to excessive scales offered. Therefore, this means users can experience less burden and fatigue with less scales of rating without affecting convergence when using IGA for evaluation. In the field of music composition, Unehara et al. [35] developed an Interactive Composition System, which helps compose music by searching satisfaction of audience based on user preferences and ratings. Zhu et al. [39] proposed rules for generation of emotional music and employed Interactive Genetic Algorithm to optimize the weights of these rules and thus generate the most satisfied emotional music.

In summary, IGA-related studies have shown that there are good solutions to the improvement in the assessment of human fatigue. The only exception is interior design which involves more and complicated user needs than those in other design fields, and requires user participation to obtain user preferences for optimum results from co-design efforts. HBGA (Human Based Genetic Algorithm) is a process which employs evolutionary agent model and interactive interface to allows

users to participate in evaluation. Compared to the monotonous computerized evaluation with IGA, HBGA appears to be more interesting. Therefore, the method of HBGA design can have a balance with fatigue issue and is more appropriate for co-evolutionary design in the field of interior design.

TABLE II
252 PAPERS IN THE FIELD OF GA-BASED DEVELOPMENT FROM 1980S TO 2000

	1980s	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	total
Graphic art & CG animation	2		3	2	4	5	5	2	2	4	9	4	42
3-D CG lighting design								1	3	1			5
Music					1	3	3	1		1	3	5	17
Editorial design									1		1	2	4
Industrial design				2	2	1	5	4		2	4	9	29
Face image generation			1		1	1	2		1	4	5	1	16
Speech processing & prosodic control							2	1	2		1	1	7
Hearing aids fitting										2	7	5	14
Virtual reality								1	1				2
Database retrieval								2	1	8	8	1	20
Knowledge acquisition & data mining							5	3	3	1	4		16
Image processing									1	2			3
Control & robotics				1				2		3	4	4	14
Internet										1	2	1	4
Food industry								1	1				2
Geophysics											1	2	3
Art education												2	2
Writing education									1	3			4
Games and therapy								1	1	1			3
Social system										1			1
Discrete fitness value input method								5		2			7
Prediction of fitness values							1	2	1	8	3	1	16
Interface for dynamic tasks						1					1	3	5
Acceleration of EC convergence								1	1	3	1		7
combination of IEC and non-IEC								1	2				3
Active intervention			1								3	2	6
total	2	0	5	5	8	11	23	28	22	48	57	43	252

III. Research Method

Building a complete design platform takes a long time as it covers extensive areas. This pilot study aims at exploration and research of methods, providing interior designers a communication design method and platform to obtain the potential needs of the users in an efficient manner. The human-based co-design service platform must be developed in three major phases in proper sequence as shown in Fig. 2. For the purpose of the study, the concept of information sharing among interior designers and users (clients) will be introduced initially to analyze and create the actual co-design and data workflow. This study will also provide the description of the design case in which the method is employed, for the purpose of analyzing various considerations and characteristics of the transformation under each communication phase, and further defining a co-design model to be used in innovation service of interior design. With all these efforts, the module factors required for subsequent platform development may be found. The details of the application and content of the method are described as follows:

A. Multiple-Case Study

Multiple-case study has pros and cons compared to a single-case study. In a single-case study the study objects are selected based on the selection principles such as uniqueness, criticality, or inspiration while in a multiple-case study it often takes more time to collect more extensive data. In an interior space of residence, living room is a public sphere and a family activity center. It is the space of most practical use and with largest area. Therefore, living room plays a major role in determination of the design style of the entire space of residence while the determination of design style is helpful in the communication between designers and users. Therefore, this study currently provides contents recorded from design-related communication between designers and users by leveraging a half participant observation method and a structured interview. User's (client's) preferred styles in an example of a 50 to 66-square meter living room, such as illumination, color and materials, may thus be understood and recorded. Through discussion of design requirements with the designer the user received design related knowledge repeatedly and eventually obtained the final design idea drawing. In order to effectively document innovative ideas derived from the design process and save the professional knowledge for future design reference, the user also utilized this platform to propose design requirements and save the personal service information for the purpose of future evaluation and analysis.

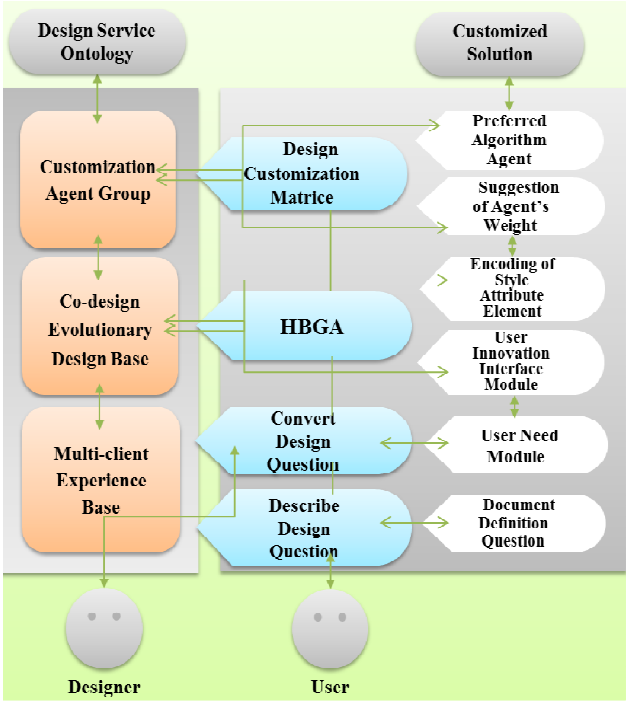

Fig. 2 Framework of human based co-design service platform

B. Description of Design Question: Documenting and Defining Question

In this study feedbacks from users (clients), or various situations caused by various factors were used to create the content of task items through the mechanism of discussion set up under project management. A Co-design Interactive Communication Map was drawn in the initial stage as shown in Fig. 3. This map was used to create a modeled structure of co-design knowledge for interior design, offering an intuitive method of documenting interrelations among documents and associated knowledge, to identify conversion of data and the sequence of data generation. The repeated data can thus be re-used and shared, and the relevance between the client's feedbacks and design specification may be identified through the documents of communication map. Similarly, the information created by the co-design task of interactive communication map in this study will be utilized as the critical design element in the subsequent co-evolutionary design base.

Users' (Clients') ideas, perceptions, and dreams for the future in connection with requirement design are derived and collected through interactive communication. In other words, the designer needs more messages that influence the experience of interaction between users and design objects to design a design object that complies with users' experience and meets their expectation. These messages, combined with expertise and knowledge of the designer, are recorded in the requirement record chart to explore in depth the experience and needs of users and then proceed to the co-design evolutionary process in the second major stage.

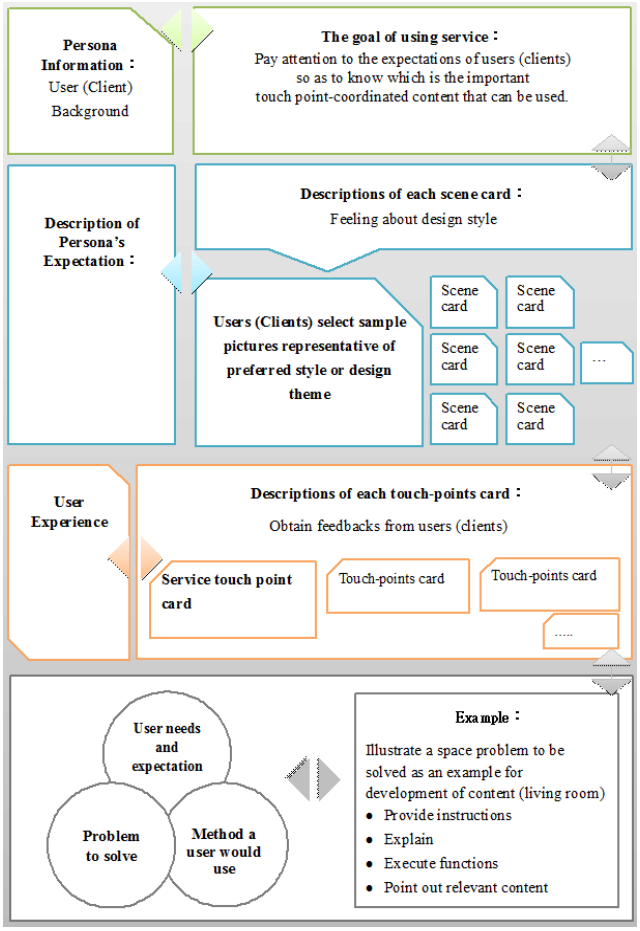

Fig. 3 A co-design interactive communication map

C. Converting Design Question: User Demand Module

Users' questions for needs are often unclear, vague, and general. The question definition for space requirement must be made for different users (clients) by working with the designer based on information and user life experience communicated between the designer and the user. Through judgment, analysis and conversion, the co-design model can then be defined and saved in the client's experience base.

Due to tediousness and complexity involved in interior design question, the designer will provide design expertise and conception service based on design knowledge, build the framework of demand module, analyze the attributes of style and genetic elements, and define the gene-preferred module and formation rules. The data partitioning may therefore meet the re-creation conditions of service combination design elements. Moreover, once the user preference information is analyzed, it is saved in the clients experience base as the basis of subsequent platform design evolution, while, on the other hand, it will be used as a basis for improvement and subsequent evaluation to determine whether user-customized optimum result is achieved.

D. Multi-Client Experience

The focal point of a Multi-client Experience Base lies in the client's statement. The coverage of rules can be expanded by leveraging the question descriptions stored in the client's base, and the status and results recorded, thus forming the core functions of knowledge base and building available knowledge base, not merely database. Such an experience base will expand and evolve with the increase of the designer's experience, plus the feedbacks for design process given through interactions with the user. Through the mechanism of the user's interactive communication map the gene combination rules generated in the second stage of the platform can be provided.

IV. Suggestions to Subsequent Studies

Through investigating innovation communication service experience between users (clients) and interior designers by using co-design method, defining a co-design model to be used in interior design innovation service, and further exploring the influence from users' (clients') involvement in co-design, the suggestions and contents may be proposed for building a subsequent co-evolutionary design service platform.

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