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The Role of Design Eureka in Design Thinking

Yi-Cheng Chiang
Chaoyang University of Technology, Taichung County, Taiwan
saphi@ms62.hinet.net

1. Introduction

Design research domain has been studying design as rationality for a long time. Most of design researches have paid attention to the rational aspect of design, such as systematic process, design reasoning, design knowledge and so on. These accomplishments constitute the body of understanding about design so far. However, one of the most fabulous things in design is at certain point a novel idea occurs incidentally, and by which better solutions suddenly become possible. Such a flash of insight really exists in many design processes. This particular phenomenon of design solution-discovery could be called as "design eureka". Experienced designers may enjoy this kind of eureka from time to time, but never be able to catch it methodically. The esoteric wonder as such defies simple explanation, but might not be totally ineffable. It is the intent of this paper to provide a way of conceiving this phenomenon of design eureka that hopefully can be in better position to understand it more clearly.

In cognition psychology, "eureka" is described as a flash of insight usually after a period of intense preparation during which the thinker is totally immersed in the problem and approaches it from all possible angles, but illumination tends not to come then. And then suddenly the solution arrives, not at the writer's desk or the composer's piano, but elsewhere entirely (Gleitman 1995). Psychologists propose that this kind of creative thinking may involve perceptual restructurings, conceptual reorganizations, and incubation effects. Although there are some researches about these cognitive processes, few theories really prevail.

Some studies of creative design observe this phenomenon as "creative leap" (Cross 1997, 2001). The idea of a "creative leap" has for some time been regarded as central to the creative design process. By protocol study, the creativity in design is observed closely and deeply, but there are some methodical defects in these researches, in which the discussions of designers' thinking are always full of subjective interpretations, guesses and uncertainties. Even if some important observations and interesting suggestions have been made therefore, these accomplishments are difficult to examine in detail because of the lack of clear analytic procedures.

As what the cognition psychologists has revealed about the "critical insight", this phenomenon of thinking happens in design, too. Design eureka is a real experience independent of the quality of design work and could happen in various designs. To clarify the thinking mechanism underlying this mysterious design eureka, the present paper excludes the judgment of design work. To dispel the mystique of design eureka, the present paper aims to develop an effective measurements to capture it precisely. And then the advanced analysis could have a secure basis.

2. Issues and Viewpoints

2.1. eureka and bottleneck

As the stories what design practices tell, no matter creative or not, designs get into bottlenecks occasionally. The bottlenecks of design don't occur at the beginning of design, but only after some vain efforts of solving particular design problems. It is this moment of bottleneck that indicates the limits of knowledge and heuristic reasoning in designers thinking. Therefore designers look for any inspiration to break through the situation of bottleneck. Usually but suddenly, "design eureka" comes out in the following period and always from elsewhere not in the memories. This phenomenon reflects a kind of pair-like relationship between the bottleneck and eureka, and represents a critical type of thinking different from the logical or heuristics ones, but important for acquaintance with designers' thinking beyond rationality. The present paper defines the pair of "bottleneck" and "eureka" as two core agencies of "design eureka" whose meaning to thinking should be studied in a context containing both two.

2.2. eureka and navigation of problem landscape

"Design eureka" is so sly to describe precisely, not to mention to explain it. Therefore the preliminary issue of research is how to describe this "event". The way we describe it reflects how we view design thinking. Design thinking can be viewed as a process of navigation in a "problem landscape" which is dynamically changed along design process. The landscape is created and recreated in response to each move of design decision, and is constantly in the state of flux. Therefore, design navigation is never a programmable journey in a static problem landscape. The fact is that there are very few cases in which design problems can be formulated once and for all at the beginning. Problem changes as design develops, design navigation shall be seen as a trip to the landscape which itself is reciprocally shaped by that trip.

According to several preliminary observations, design eureka functions more likely as an effective act of changing the problem landscape into become more plausible for forming solutions, rather than as an effective solution per se. In this light, "changing-problems" instead of "solving-problems" holds the key to the design eureka. Problem reformulation requires insightful perceptions that can be molded by diversified resources, sometimes are dubious heuristics, hybrid ideas, or even irrelevant analogies. In the hierarchy of design thinking, design eureka plays at strategic level that gives instructions to the lower level of design operations, and is affected by the designers' intentions/philosophies from the level at above.

From above viewpoints, the dynamic changing of problem landscape and its navigation develops a time axis of thinking activities, which always play special thinking functions. And design thinking functions could be

divided into three levels: intention level, strategy level, and operation level from top to bottom. There are three main questions this paper try to answer that how design eureka act among these functions, when it comes out, and where comes from.

3. Protocol Analysis

This research started from the study of real-world design protocol in order to as close to the actuality of design eureka as possible. Twenty real-world design protocols were collected. Each protocol came from different designers with different design programs, but all have experienced their own design eureka. Designers were asked to report their design processes in order of time and avoid any additional explanations and judgments. They were encouraged to retrospect design process and concurrent thinking with their original design sketches, drawings, models, or any related objects. In these protocols, designers always described the whole skeleton of design processes and communications with clients or other experts. But designers always elide most details except on key problem development, how they treated these problems, and on the occurrence of an important sudden idea. Besides designers' retrospections, researchers have distinguished the additional statements and clarify any confusion or ambiguity by checking with designers. Before any analysis, designers' oral reports were translated into literal protocols.

3.1 protocols

For deeply analysis, four of the twenty protocols were chosen according to their diversities, which are preferred by this research in order to find out the common mechanism underlying the apparent varieties. The more diverse these protocols are, the more representative the mechanism is. These four protocols and designers are numbered as 01, 02, 03, and 04 in this paper. Protocol-01 is the shortest one but with clear phenomenon of design eureka as the others are. Protocol-01 is chosen as an illustration in this paper. The following introductions are a summary of protocol-01.

Protocol-01 is a shopping-mall design. At the beginning, the client demanded that the building should display an image of the Liberty to present the project's name "New York", even if the building will stand in Taipei. Designer-01 almost could not accept this demand. He preferred the building to be "simple". But he still tried some schemes by massing study and refused to design in post-modern style that is preferred by the client. At first, the client cannot accept his proposal without any of the Liberty's image. But designer-01 never gave up his own desire of the simple. He reinterpreted what the client asked for an image of the Liberty as a desire of "the remarkable". In one hand, he explained to the client how the schemes perform the image of "New York" replacing "the Liberty". In the other, he tried to communicate with the client to conceive different ways to be "remarkable". After several presentations and communications, the client finally accepted one of designer's massive-remarkable schemes. But at this time, designer-01 himself reversed his scheme and looked for another simpler one. Although having proposed several massive schemes, designer-01 still has no idea about how to make the building simple but remarkable with the image of "New York". One day when he was thumbing through a magazine, a glimpse of a particular building picture fired him a flash of light. He transformed partial composition of the elevation of that building into a new concept of design. He was

satisfied with the new solution very much. In a later review, designer-01 certified again that the simplicity of the new design is actually what he has wished for.

3.2. encoding

The most critical differences between real-world-design protocols and lab-experiment ones is that real-world design is in a complete open environment, where nothing is controlled by the researchers, even the factors studied. Most of experimental protocols are conducted in a clearly defined and closed environment, where design information is static and controlled. While real-world design never proceeds like that but is always full of changing and unexpected events. Since design environment is open, more information or events can get an opportunity into design discourse. It is a particular phenomenon in these real-world-design protocols that each designer reported a special event or activity, which is outside ordinary design process but makes critical influence on their own design. It is the first issue of coding system that how to encode the "openness" of real-world design so as to analyze its role in design. The second issue of coding system is about the common mechanism of diversities in these protocols. Unlike experimental protocols with standard design assignments, real-world-design protocols faced with different design briefs. The coding system should present the common structure of thinking mechanism underlying each protocol. Chronology of coding system is the third issue. In this research, the role of design eureka in design thinking should be discussed in a history of design process. The main task of coding time is not to present the absolute time but the relative sequences of process.

This research integrated these three issues together to develop a two-dimension coding frame, which contains a notation system and a time-scale table. The way this paper studies design protocols is to encode them into a table called as "the context-table". The context-table has two main targets: one is to show the designer's thinking episodes, which are some design segments, and the other is to show their changing paths. For the former, we identify "eight factors" from protocols to describe the thinking episodes. And for the latter, we create a "time-axis" of description to reveal the sequential changing.

Even if the four protocols come from totally different design situations, there are still some common structures in their cognitions. At first, all of them have not begun from nothing but at least a requisite. The requisites always existed before design. Some are the requirements of clients as protocol-01, protocol-02, and protocol-04. And specially, some are designers' own intentions as protocol-03. In most of design researches from problem-solving theory, designer's intention is never considered seriously, and only briefs of client are discussed and regarded as design problem. However, in protocols, all designers reported their design intentions or preferences. And the design problems reported are some unsatisfied conditions of designers' particular intentions or ideas, or some conflicting situations between requirements and designers' intentions. And these reports of problem occurred not at the beginning of design but only after a period of design development. These phenomena indicate that a design brief is not equal to a design problem in design cognition and that designer's intention is an important factor of design. Designers proposed their own intentions on design at early stage and treated these intentions no less important than briefs. Most of time, designers didn't change their intentions for solving problem more easily. And what is more in protocol-01, although one solution was adapted to brief requirements, designer-01 gave it up finally because it was not conformed to designer's own

preference. In protocols, briefs and intentions are considered as information outlining the goal of design. This research regards such a goal as the main pushing force to start design. All of designs started only after these requisites had been proposed. This research classified these requisites as "the premise" category, which means a particular privilege governing design.

Secondly, four common thinking units are identified according to the thinking function in each statement. They are "design problems", "design orientations", "design operations", and "performance evaluations". These four units constitute as "the thinking" category, which develops into the body of design thinking. In this category, some statements describe the problems designers were treating or extended considerations of problem. The thinking function of this kind of statements is on design problem-to clarify or interpret a problem and so is encoded as "design problem". Those statements, describing about some directions or strategies, which designers use to guide design, are encoded as "design orientations". The statements, describing physical ways of doing or making design, are encoded as "design operation". And the statements, describing the productions of design or giving them evaluations, are encoded as "performance evaluation".

At last, a real-world design is so open that unexpected things may come in and influence design. The unexpectedness events or activities outside the territory of design thinking are named as "the exterritorials"—a compound word of "exterior" and "territorial". By this classification of interior and exterior of thinking, this research encodes the open resources of design. And this classification reveals a question about the territory of thinking- what is the territory of thinking? We suppose that after a period of thinking, the thought will cultivate a field that is a collection of what have been thought and its direct associations. This field is the territory of thinking. All in the territory can be expected by this thinking. But outside the territory, there are unlimited content that this thinking has not touched and not been associated, which is "the exterritorials". If any of the exterritorials comes into the territory and makes work, it must inspire a surprised-feeling of the thinker/designer. And what will cause the exterritorials to come into the territory? It may be the continuous cultivation of thinking itself. This work could extend its territory but not inspire any surprising. Here needs some different ways to associate and to cause surprising. It must be an unexpected association that connects to the exterritorials unexpectedly. And the unexpected association needs particular unexpected event to fire. In these four protocols, what makes the unexpected association is always a particular unexpected event. The facts in the protocols have support our hypothesis.

From above, the context-table consists of three divisions representing the three categories: the "premise-division", the "thinking-division", and the "exterritorials-division". Each division covers several columns of table. Eight factors are classified into the three divisions (see Figure 1). The "premise-division" contains design requirements (abbreviated as "Rq"), design constraints (Cs), and designer's intentions(DI). It is the "thinking-division", containing design problems (P), design orientations (Or), design operations(Op), and performance evaluation(E), that actually perform design. In the "exterritorials-division", because there is no enough data for detail classification, all of this kind of statement are belong to the only one unit- exterritorials(Ex).

In the context-table, a protocol is divided into several design episodes named as "design section". Every section unfolds a row of the context-table and consists of the eight factors in the three divisions. Each factors leads a column and each division stands on an area with their factor columns. So each protocol's context-table contains several section-rows and eight factor-columns. There is a sequential rule governing the order of the three divisions and their eight factors (see Figure 1). According to their roles in whole design cognition, the sequence is determined and begins from "the premise-division" through "the thinking-division" to "the exterritorials", from left to right.

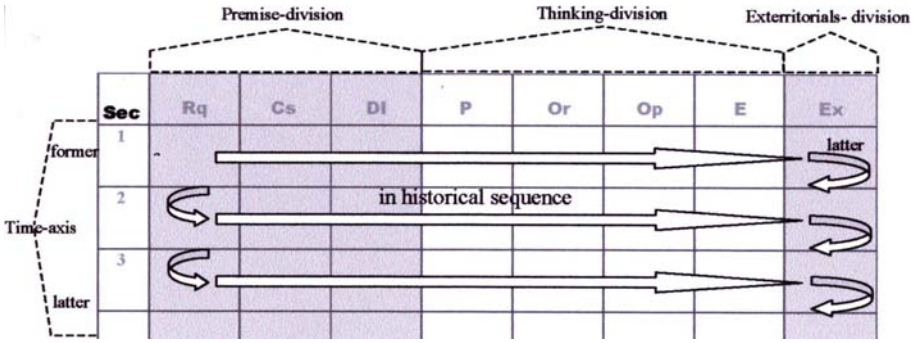


Figure 1. Conceptual frame of encoding system in the context-table

All protocols were encoded into the context-table, statement for statement. First, according to the factor attribute of statement, each statement was noted as a suitable abbreviation on its matching blank. Secondly, according to content of a statement, we judged its relation with other statements and formulated its relation-equation. For example:

P1= DI1+Rq1.2 (1)

Equation (1) means that P1 relates to DI1 and Rq1.2. In fact, it may be that P1 was a result influenced by DI1 and Rq1.2. In later analysis, the relation-equations can be transformed into relation-networks in relation analysis. Here is the context-table of Protocol-01 (see Table 1). There are two kinds of empty blank: Blank-# and Blank-◎ . Blank-# means that it has no other information from protocol but inherit the same information from above blank. For example, Blank-Rq2 is noted as "#", because of that designer reported nothing about that requirement, which means that no design requirement has changed and so the previous requirements had been maintained. On the contrary, Blank-◎ means that there was no information from designer's report and in fact nothing happened in the immediate thinking at all. All of he empty blanks of the "thinking-division" will be Blank-◎ . Note "☆" represents the occurrence of eureka-idea and "※" the end of design.

TABLE 1. The context-table of Protocol-1 as the result of encoding

Sec	Rq	Cs	DI	P	Or	Op	E	Ex
1	Rq1.1 Rq1.2	Cs1	DI1	P1= DI1+Rq1.2	◎	◎	◎	◎
2	#	#	#	P2= DI1+Rq1.2	Or2	Op2	E2	◎
3	#	#	DI3	P3= DI3+Rq1.2	◎	◎	◎	◎
4	#	#	DI4	P4= DI4+Rq1.2	Or4.1 Or4.2	Op4	E4.1 E4.2	◎
5	#	#	#	P5= DI4+Rq1.2+ E4.2	◎	◎	◎	Ex5.1 =DI4+Rq1.2 Ex5.2 =Rq1.2 ☆
6	#	#	#		Or6	Op6.1 Op6.2 Op6.3	E6	◎
7	Rq7	#	#	◎	◎	Op7	◎	◎
8	#	Cs8	#	◎	◎	Op8 ※	◎	◎

3.3. analyses of Pattern

3.3.1. Methods

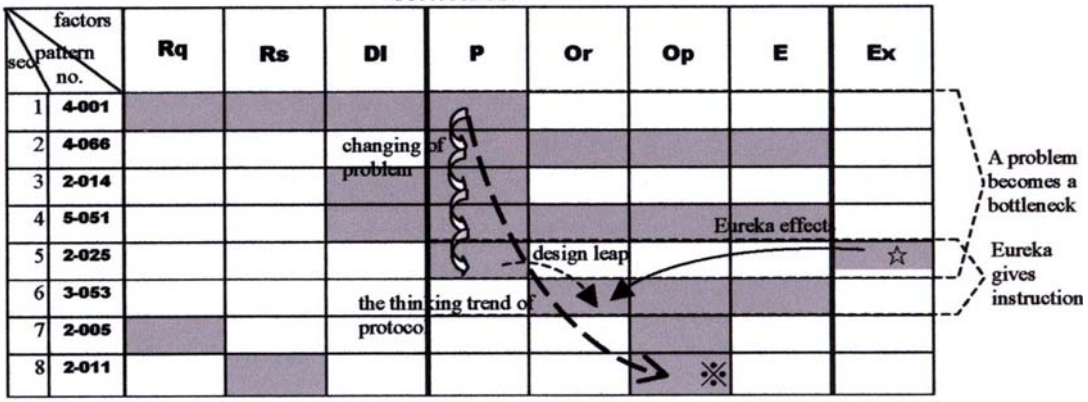
In pattern analysis, we blackened those information-noted-blanks firstly. And then the thinking pattern showed up. This kind of pattern pictures the historical traces of thinking through design processes which designers have reported. After removing content information, pure mechanism can be read from the patterns (Table 2). The pattern analyses of each protocol are shown as Table 3. Two directional advanced analyses have been done. One is horizontal analysis, whose goal is to observe detail thinking performance in each design section. The other is vertical analysis, whose goal is to observe the changing and developing of each factor. And the integration of these two analyses can induce the trends of whole design process. Particular patterns of problem bottleneck and design eureka could be pointed out from tables.

TABLE 2. The pattern-table of Protocol-01

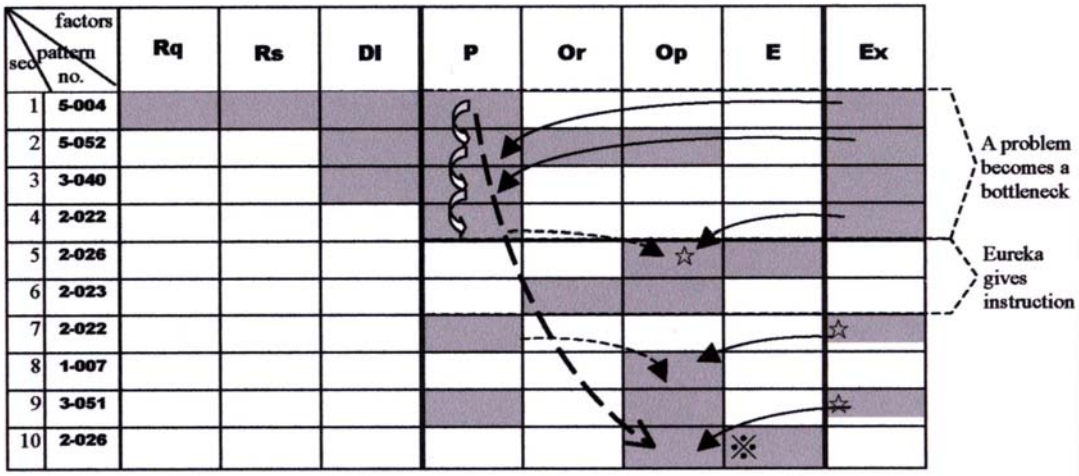
sec \ factors / pattern no.		Rq	Rs	DI	P	Or	Op	E	Ex
1	4-001	■	■	■	■				
2	4-066				■	■	■	■	
3	2-014			■	■				
4	5-051			■	■	■	■	■	
5	2-025				■				☆
6	3-053					■	■	■	
7	2-005	■					■		
8	2-011		■				※		

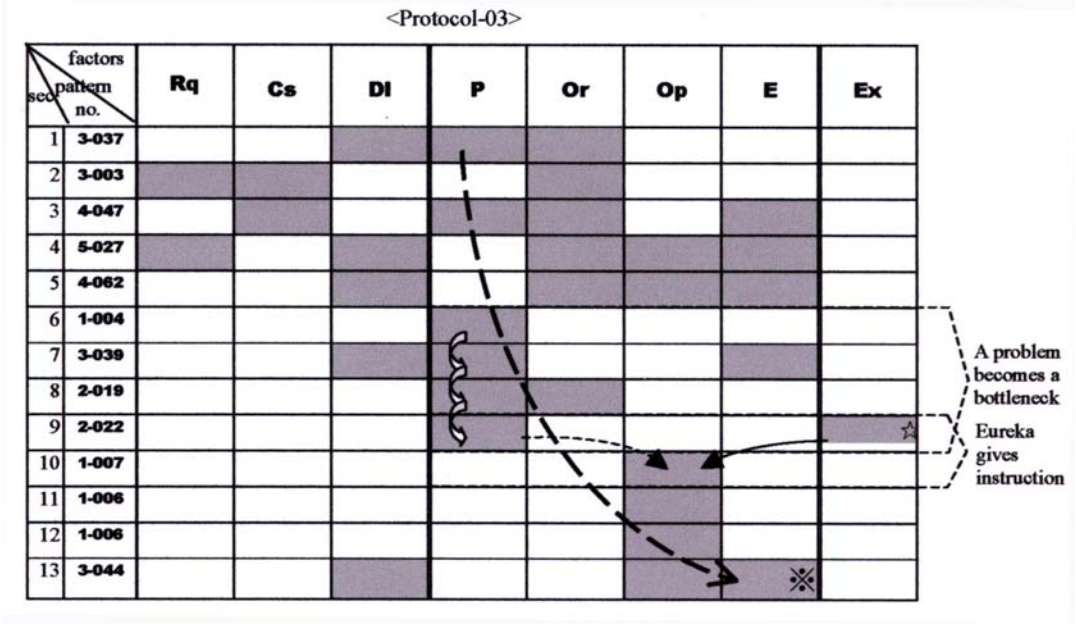
TABLE 3. The analysis of the pattern-table of Protocols

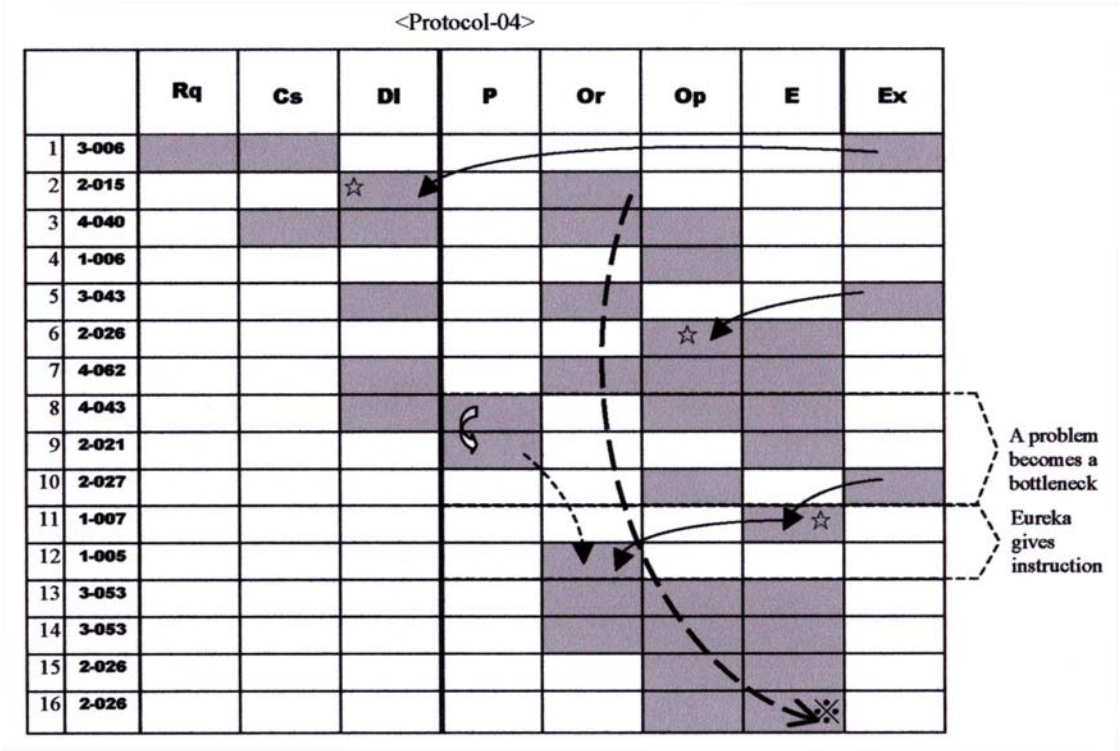
<Protocol-01>



<Protocol-02>







3.3.2. Findings and Discussions

Followings are some major findings of pattern analysis:

1. The pattern can reappear the thinking history by the eight factors.

(1) Various thinking phenomena, such as "bottleneck", "eureka", etc., have their particular patterns.

(2) All trends of patterns develop toward right side-- design operation and evaluation. This result conforms to the goal and the discipline of design-- to generate a physical form by operations.

(3) Each of the four protocols has its own thinking pattern, which appears characteristics of protocol. The type of pattern seems indicating at some degree the style of design thinking.

2. Design eureka can be identified clearly from the thinking patterns.

(1) Design eureka always comes from the exterritorials or their inspirations. Some idea-eureka happened just when particular exterritorial events were proceeding. And some happened when the exterritorial events have come into the thinking field and were combined with the originals.

(2) There are two different preceding conditions of design eureka: one is with a problem-bottleneck, and the other is without any problem-bottleneck, even any problem sometimes.

(3) After the occurrence of design eureka, the next pattern must start from the righter factor blank than the problem. It seems that eureka has stretched the trend of thinking toward design operation right side. This result represents the thinking function of design eureka—a "jump" to next more detail design stage.

3. Before the bottleneck-problem, there is always a collection of problems through one or more previous design sections. This finding indicates the evolution of design problem.

4. In the premise-division, the designer's-intention column changed mostly through sections. According to the patterns of four protocols, the designer-intention column changed always accompanied with a problem changing or a new operation. The results indicate a guidance of designer's intention to design.

3.4. analyses of relations

3.4.1. Methods

The analysis of factor relation is to study thinking process by the dynamic reactions between factors. The dynamic reactions can be described as a relation network. This kind of network aims no detail content, but to illustrate the information-processing flow behind the relations. From this kind of network, this research figures out the role of design eureka in whole information-processing flow. Firstly, the previous formulations of relation in the context-table should be transformed into a relation-network (Figure 2), where the node of network is the matching blank in the context-table and marked with its abbreviation, and the arrow connects the node with other related nodes. Secondly, the thinking route should be identified from the network by connecting the arrows in the thinking-division. And the "shortest thinking-route" also could be identified by connecting the shortest and continuous arrows from bottom to top. The third step is to analyze the network in order to infer the interactions between factors. The analyzed relation-network of protocol-01 is shown as Figure 3.

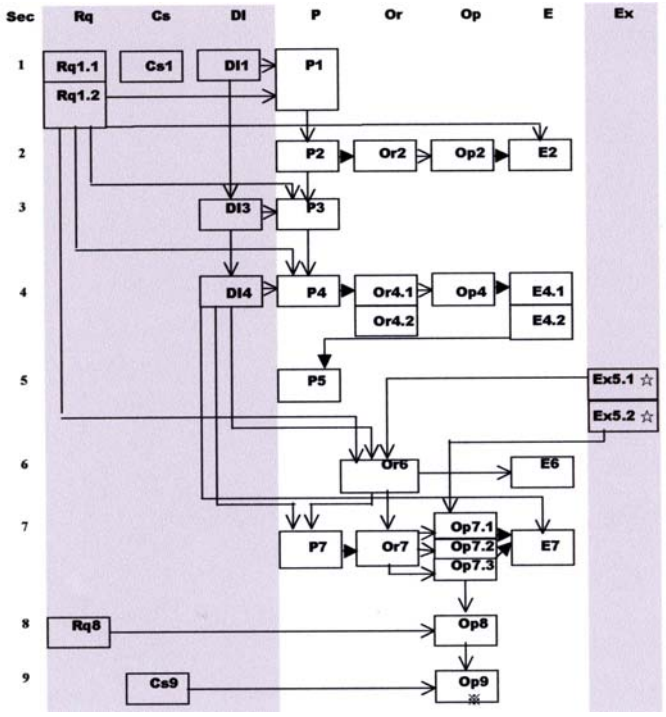


Figure 2. The relation-network of Protocol-01

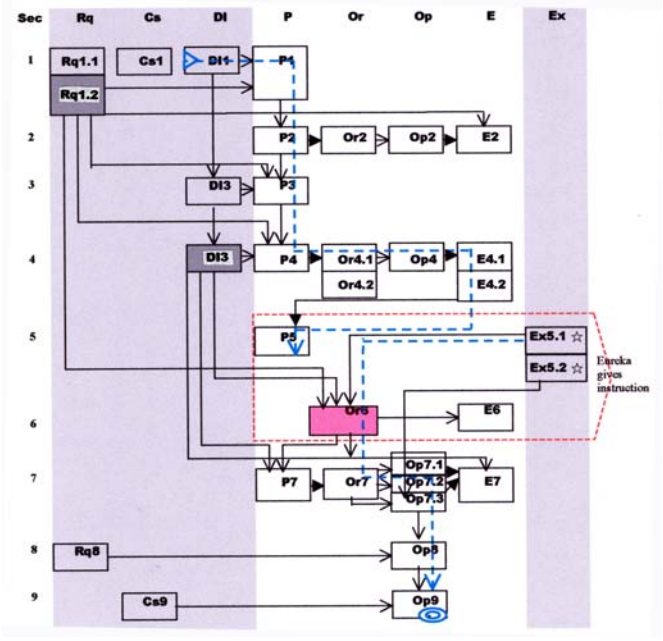


Figure 3. The analysis of relationship-network of Protocol-1

3.4.2. Findings and Discussions

Some results have been found as followings:

(1) The information of each factor could go into other factors and influence them. This phenomenon results in the flow of information between factors through design sections.

(2) According to thinking route, the major thinking developed along its route in the thinking-division and the other two divisions supplied necessary information to the route.

(3) Two special types of node can be identified: one is the gray node, which shoots most arrows to others and represents the most influence on others. The gray node is named as " the most influential node". The other is the purple node, which receives most arrows from others and represents the factor, which receives most attention. The purple node is named "the most critical-decision node".

(4) There is one or more disconnected place of the thinking route, where is exactly the "design ditch". And it is exactly the design eureka that continue the stopped thinking route by "jumping" or "bridging" the "ditch".

(5) There are two ways that design eureka continues the stopped thinking: one is that design eureka starts a new beginning as a "jumping"; the other is that design eureka offers a connection with the previous stopping node and directs the succeeding thinking, as a "bridging".

(6) All of four relation-networks locate " the most influential nodes" on particular "designer-intention nodes".

(7) Most of thinking-route started from design problem, but protocol-04's thinking-route didn't. Protocol-04 started from design operation and emerged the first design problem very late.

4. Conclusions and Discussions

4.1. the role of design eureka

From protocol analyses, this research concludes three characteristics of design eureka:

(1) The functionality of design eureka: All design eureka offers some inspirations for problem or a bottleneck and move the stunted design ahead. It play a functional role in deign thinking.

(2) The situationality of design eureka: What make an event or idea able to give useful inspiration is not because its content is special. It is because this event or idea is particularly suitable for the problem situation. Only when design problem evolved into a particular situation, the relation-network could generate a successful connect to that idea, otherwise that idea was not helpful at all.

(3) The exterritoriality of design eureka: In all protocols, design eureka comes from the inspiration of particular events or activities, which are always outside the ordinary design process. This critical characteristic could be called as "the exterritoriality", which cannot be considered in a traditional closed research situation, but could be cognized and analyzed in this new open field. The boundary of territory represents not only the difference of closeness and openness. What is more, for human thinking, it reveals the limitation of rational reasoning. Design eureka, coming from outside the boundary, therefore could provide a way to transcend such a restriction of limitation and break through the bottleneck of rationality.

4.2. Performance of analytic methods

This research has developed a series of effective analytic methods. By graphic description of table and figure, dynamic history of design navigation is visualized. In these visualized analyses, this research has successfully pictured the scene of design eureka within the circumstance of real-world design. The performance of the graphically analytic methods finally overcomes the difficulties of description and explanation of design eureka. The result suggests that it is necessary to improve our instruments in order to catch deep thinking characteristics. And the methods this research applied could be offered as an example. In pattern analysis, the patterns of thinking change as design develops and so can be regarded as a representation of the changing landscape of design navigation. Each protocol has its individual type of pattern, which reflects the style of its design thinking at certain degree. It could be applied for future style studies.

4.3. design as designer-devoted art-working

Besides the results of analysis, there are some findings disturbing some typical viewpoints of human thinking. A finding about design problem comes from the absence of it at the beginning of design. In Protocol-04 particularly, design problem didn't appear until the middle stage of design when most of form has been generated and is very good. Such design event indicates that the designer didn't recognize any problem during that period, and if not problem-solving, what did the designer really have done and how might that thinking? This case offends the opinion that views design only as a kind of problem-solving and suggest that we should reconsider the meaning of "design problem" for real human thinking, but not only for artificial thinking.

According to this research, design problem is not necessary to be functional requirements as some other researches have conceived, all of these four protocols got their problems and bottlenecks little related with clients' brief but much with designers' own intentions. We argue that it is this way that designers devote themselves into design, and then makes design thinking to go beyond the problem-solving scope and into the art-working one.

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