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IDEA-SPACE SYSTEM ANALYSIS: THE STUDY OF AN IDEA-CREATION SYSTEM FOR CATALYZING BREAKTHROUGHS

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Keywords: idea-space system analysis, idea creation process, breakthrough, systems architecture, systems engineering (SE)

1. Introduction

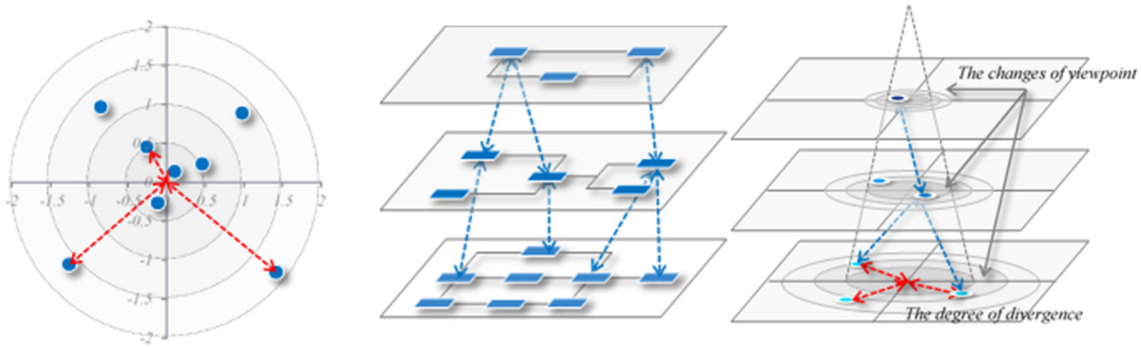
Innovation and creativity are the most important company capabilities for sustainable and resilient growth. According to a survey of global Chief Executive Officers (the IBM Global CEO Study in 2010), "Facing a world becoming dramatically more complex, it is interesting that CEOs selected creativity as the most important leadership attribute" [IBM 2010]. In recent years, numerous studies have been conducted on the generation of ideas or breakthroughs, including those on participant diversity, ways of thinking, and idea generation methodologies. In terms of member diversity, Anita Williams Woolley confirmed the concept of team collective intelligence, which is group performance ability on more complex tasks. She found that group intelligence was enhanced by the proportion of females in the group, increasing member social perceptiveness [Woolley 2010]. Lee Fleming indicated that in a creative team comprised of similar disciplines, the average value of innovation became higher, however was still unlikely to achieve a breakthrough; a group consisting of more diverse disciplines was more likely to achieve such breakthroughs [Fleming 2004]. Henry Chesbrough advocated the open innovation concept, which is the effectiveness of collaboration with another organization or company rather than one's own for creating new value [Chesbrough 2005]. As a methodology, "design thinking" has been paid the most attention. "Design thinking is a methodology that imbues the full spectrum of innovation activities with a human-centered design ethos" [Brown 2008], [d.school teaching team, 2010]. In other words, the human-centered way of thinking involves understanding people through direct observation, and this then becomes the source of innovation.

During the idea creating, everyone has an experience getting stuck on. In the past study, in order to break through the stalled process and generate new ideas, systems thinking–based methodologies or innovation processes have been studied [Imaizumi et al. 2013], [Yasui et al. 2013]. The understanding of the key factors for catalyzing breakthroughs is still far from complete. In this study, in order to establish a methodology of consecutive idea creation, this study focused on the elements for catalyzing breakthroughs. This study has focused on the long-term project or workshop, because idea creation will be getting harder to generate new ideas with time, even though the team has great diversity of participants. Therefore, the key elements for breaking the situation of getting stuck have been investigated with systems engineering approach. As the analysis method, systems engineering based idea-space systems analysis was proposed, which combines the degree of idea divergence analysis and idea systems architecture analysis.

2. Method

In order to analyze the mechanism of a breakthrough, systems-engineering based approach was applied

in this study. As the sample, all ideas and contents of a discussion were recorded over the entire period of a long-term workshop. The proposed "Idea-space system analysis (ISSA)" was applied to the study of breakthrough mechanism. ISSA consists of two analyses, the degree of divergence analysis and the systems architecture analysis. For the degree of divergence analysis, the correspondence analysis for each idea was conducted. (Figure 1 (a)) Calculated distance between ideas was defined as the degree of idea divergence and the timing of discontinuous changes in divergence was determined as the breakthrough timing for the duration of the idea creation term. All the ideas and the contents of the discussion were defined as a system, the system architecture analysis was carried out. (Figure 1 (b)) Based on the results, the changes in viewpoints were investigated in the idea generation history. Finally, by combining the two results obtained from these analyses, the degree of idea divergence and the idea systems architecture, the elements for catalyzing breakthroughs were studied. (Figure 1 (c)) By using these analyses, we know "How much and when does breakthrough happen?" and "Why does it happen?".



(a) The defree of divergence analysis *(b) The systems architecture analysis* *(c) Idea-space systems analysis*

Figure 1. Idea-space systems analysis

2.1 Idea creation in a long–term workshop

In this study, we defined "long-term workshop" that team composed same members tackles a task throughout a period of time. Research target is the project such as creating new products or services on the same theme with the same members. It is distinguished from the workshop or "idea-thon" which is conducted by a temporary team between participants on the spur of the event.

As the long-term workshop, we selected the "design project" at the Graduate School of System Design and Management of Keio University (Keio SDM). The graduate school was established in 2008. Keio SDM is an interdisciplinary school that integrates the humanities and sciences on the basis of systems engineering, system thinking, design thinking, and project management [SDM 2016a]. In the "design project," which is a representative class at Keio SDM, students work on the design of innovative system concepts. It is a collaborative program with the faculty at Stanford University and the Massachusetts Institute of Technology in the U.S. and the University of Adelaide in Australia, and Delft University of Technology in the Netherlands. Students can also take a variety of subjects that deepen their expertise, polish their skills, and give them a more global perspective through group learning [Ishii et al. 2009a,b], [SDM 2016b]. The study period is a half-year, which consists of a Learning Phase, an Active Learning Phase, and a Design Phase. The phases are nine, five, and 10 weeks, respectively, as shown in Table 1. Five to eight people form a team, and the design project is conducted as group learning. Each team gives a presentation on their ideas at the end of the project. In the Learning Phase, Keio SDM professors and instructors explain idea creation and converging methods and methodologies, including the background research and the way of applying. These methods and methodologies include systems engineering methods and design thinking based on concepts used in systems engineering such as the "V-model." The features of these methods are classified into "decomposition and integration" and "design and verification & validation," as shown in Figure 2. In the Learning and Active Learning Phases, students practice the way of thinking by using these methods and methodologies to real issues or cases with team members. Students teach each other within the team, and have a presentation the idea obtained by using the method, in front of all instructors and other teams at the end of the phase. This mechanism of mutual learning helps student understand these methods and methodologies correctly. At the Design Phase, each

team works on the design of innovative concepts and systems [Ishii et al. 2009a,b], [SDM 2016b]. The evaluation of the result obtained from the design project has been taken out by professors, instructors and students. And the evaluation items are novelty and feasibility. And some teams which have outstanding idea or plan, implement their idea, some teams carry out verification their idea through design or business plan contests.

Table 2 shows the profiles of the members targeted in this research. Five individuals in their twenties formed one team. The team consisted of members with a high level of diversity from different nationalities, with a ratio of men to women of 3:2. And all the ideas and contents of the discussion were recorded through the entire period of "design project".

Table 1. Design project timeline and learning modules of design projects at Keio SDM

Phase 1:Learning Phase 1st - 9th week	Phase 2:Active Learning Phase 10th - 14th week	Phase 3:Design Phase 15th - 24th week
Learning method and methodology Design Thinking Systems Thinking Systems engineering	Team Formation Setting the Theme Apply Learned Methods	Solution Design Final Presentation

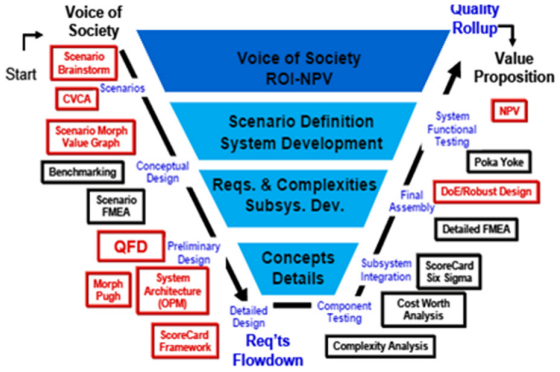


Figure 2. System development process in Keio SDM: the V-Model and associated methods and tools [Ishii et al. 2009a]

Table 2. Workshop participants' attributes

Specialized field	Nationality	Gender
Applied Physics Philosophy	South Korean	Female
Physics	Japanese	Female
Mathematics and Informatics Engineer	Vietnamese	Male
Mechanical engineering	Thai	Male
Information Science	Japanese	Male

2.2 The degree of divergence analysis

As the first step of the idea space systems analysis, the degree of idea divergence was analyzed for all the created ideas. In order to measure how much degree of divergence an idea has quantitatively. The degree of divergence is calculated by using two analyses; Morphological analysis and Correspondence analysis. First, each idea is broke down into the smallest meaningful element of a word with Morphological analysis, which is one of the natural language processing methods. At the same time, the isolated the vital parts are determined its part of speech. Second, Correspondence analysis was conducted for the words conducted Morphological analysis. Correspondence analysis is a calculation method that remaps an item near another that has a similar concept, using cross-tabulation tables. The results calculate the similarity of words as distance in a visualized map (Figure 3). On the map of words meaning, each idea is placed at the coordinates, which is calculated the sense of the idea with Correspondence analysis. By the characteristics of the analysis, the common idea is located from the

average distance from other idea therefore it placed in the center of the map. While, the unique one is located in far from the center. Based on these analyses, the calculated distance from the center of the whole idea is defined as the degree of idea divergence. Additionally, the timing of discontinuous changes in divergence was determined as the breakthrough timing for the duration of the idea creation term.

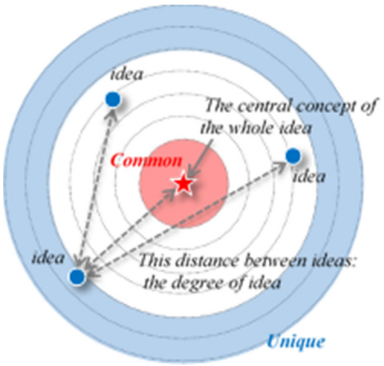


Figure 3. The degree of divergence analysis

2.3 The systems architecture analysis

According to the systems engineering handbook (INCOSEC 2011), a system is "a combination of interacting elements organized to achieve one or more stated purposes" [Haskins and Forsberg 2011]. Each idea and the entire discussion history are a combination of interacting elements organized to achieve a purpose, therefore complete ideas can also be defined as systems. We label this idea and thinking history concept as an "idea-creation system." As the second step of the idea space systems analysis, system architecture analysis was carried out for this idea-creation system. The architecture is the arrangement of functions and features that maximize its purpose. Therefore, the architecture represents the design that frames the principle, the structure of the components, and the relationship among the components [Ring 2001], [IEEE 2002]. In order to clarify the traceability between the elements or components, the system architecture is structured using three different viewpoints. The viewpoints introduced in system engineering, IEEE 1220 and DoDAF (department of defense architecture framework) standards are: operational, functional, technological, and physical [IEEE 2002], [Shirasaka 2009], [DODAF 2015].

In this research, the idea-creation system is structured with three layers, which represent the different viewpoints: physical, functional, and purpose. This will enable us to distinguish these viewpoints and to analyze the transition of these viewpoints. In order to divide ideas into three hierarchies of viewpoints, interviews and group hearing have been carried out. The group members explained the idea from recorded memos and pictures. The idea was classified into Physical layer in case user use the word "by using", "apply", "with" etc. Function layer is selected when member explains functions, ability, or capability by using the words; can, to enable, capable, enable etc. In the case that the member mentioned about the purpose, or requirement of people, it is recognized that the idea has concept of the purpose layer.

2.4 The factor analysis of a breakthrough

As the final step of the idea space systems analysis, the elements for catalyzing breakthroughs are studied by combining the two results obtained from the degree of idea divergence and from the systems architecture analyses: the degree and timing of breakthrough and the changing viewpoints.

3. Results and discussion

3.1 Idea creation results

In this research, the topic of the long-term workshop was the creation of new value for personal mobility. The personal mobility object selected was the UNI-CUB, which is produced by Honda Motor Co., Ltd. UNI-CUB is a personal mobility device, featuring a compact size, a comfortable saddle, Honda's

proprietary balance control technology, and the world's first omni-directional driving wheel system (Honda Omni Traction Drive System), as shown in Figure 4 [Yada et al. 2015], [HONDA 2016].
Sixty-four ideas were generated in total during the 15-week workshop, from the second to the third phase of the Keio SDM design project. Figure 5 presents the transition graph of idea generation. According to these results, 63% of the total ideas were generated within the first one-third of the period of the workshop. Every eight new ideas were created weekly during the term; however, the pace decelerated to one to three ideas per week after the middle of the workshop. At the beginning of the workshop, preconceived ideas were not fixed among the team members; it is conceivable that most new ideas were generated by the differences among the members. As more information was collected and more ideas generated, it was supposed that stereotypes were formed among the members. This caused members to lose their diversity, making it difficult to generate further ideas. According to the number of generated ideas, it appears that members became unable to create new ideas by the end of the fifth week.

Figure 4. Honda Motor Co., Ltd. UNI-CUB [Yada et al. 2015], [HONDA 2016]

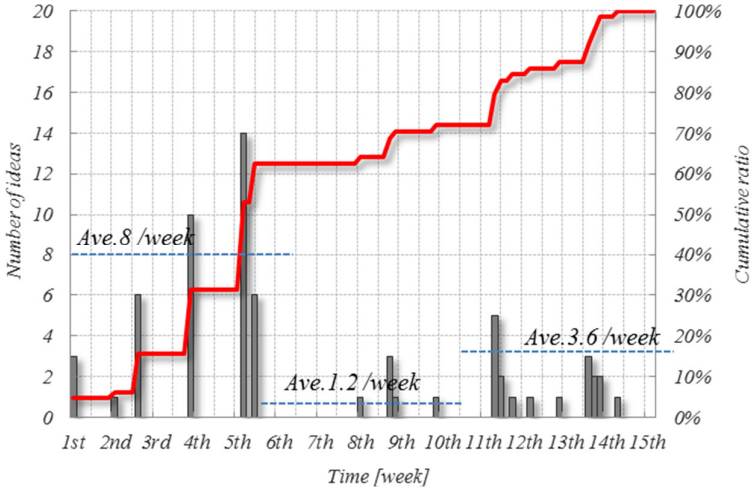


Figure 5. The transition graph of the number of ideas

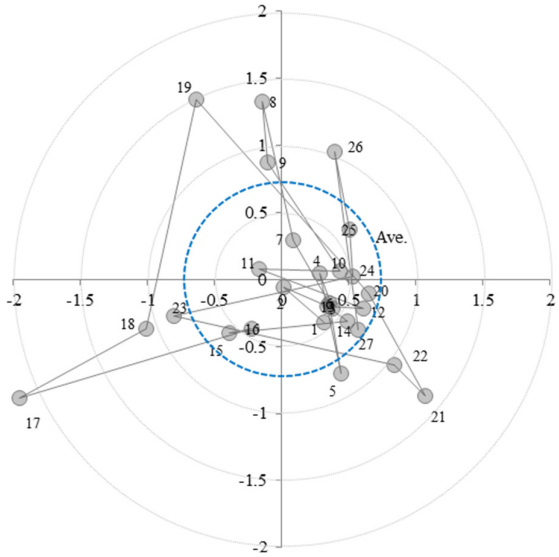
3.2 The degree of divergence results

For the degree of divergence analysis, natural language processing and correspondence analysis were conducted for the generated ideas. For these analyses, 27 ideas that finally took shape were selected out of the 64 ideas. Table 3 shows the 27 ideas. The results of the degree of idea divergence analysis are shown in Figure 6. Figure 6 (a) presents the distribution map of idea divergence. Each location is calculated looking at the similarity of idea concepts (the idea numbers are from Table 3). This distance between ideas is defined as the degree of idea divergence. From this result, the ideas can be classified into three areas: the regions around ideas No. 8 and 19, ideas No. 17 and 18, and ideas No. 21 and 22. Figure 6 (b) shows the history of the degree of idea divergence, which is based on the distance from the center of the whole idea, the origin of the map in Figure 6 (a). According to the results of the history of the divergence, it is clearly shown that the distance from the center of all the ideas rapidly becomes larger at idea No. 8 and No. 17. This implies that the breakthrough was achieved at that time. In addition,

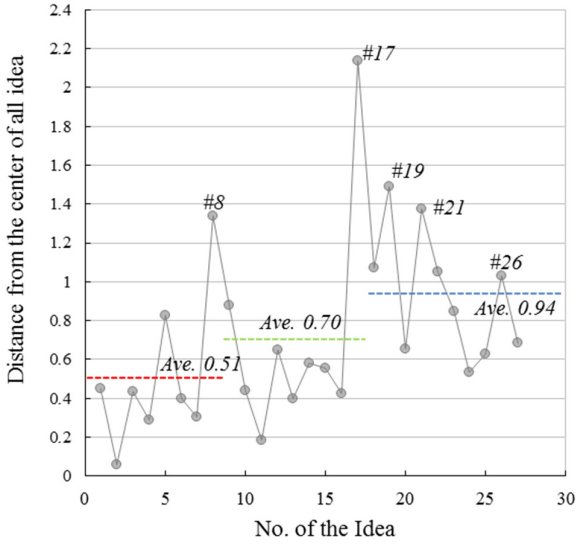
the results indicate that the degree of idea divergence became larger over the latter half of the workshop period. The average distance from the origin was 0.5 from idea No. 1 to idea No. 8, and 0.7 from idea No. 9 to idea No. 17 and 0.94 from idea No. 18 to idea No. 27.

Table 3. The history of the ideas

No	Week	Ideas
1	1st	Uni-Cub communicates each other, to work together.
2	1st	Personal mobility for the hospital. To support the movement of the user in the hospital and healthcare.
3	2nd	Using the Uni-Cub in a huge facility
4	8th	Use the Uni-Cub as chair in the creative space. The user can use both hands. And user become rich is the idea of moving the body.
5	8th	Mobility to understand the feelings of people
6	8th	Uni-Cub supports the life of the user.
7	8th	Personalize Uni-Cub using an ID.
8	9th	The Uni - Cub is carrying luggage as a porter.
9	10th	User become more sensitive, to notice a small gap by using Uni-Cub.
10	11th	The storage under the seat.
11	11th	Body trunk training mobility.
12	11th	Dog rides Uni-Cub.
13	11th	User can customize Uni-Cub by using Secretarial mode.
14	11th	Communication between Uni-Cub.
15	11th	The operation mode is changed by the user feelings.
16	11th	Using Uni-Cub in rehabilitation facilities to support to build a good relationship.
17	11th	By using Uni-Cub, ceiling height can be achieved with low building.
18	12th	Space for Uni-Cub. Movement is difficult besides the Uni-Cub user.
19	13th	Promote user's physical action. The user will want to move.
20	13th	To formalize the behavior of people make a new value.
21	13th	Sensing the unconscious behavior of people, and understand the feelings.
22	13th	Uni-Cub converts human motion into light and sound.
23	13th	The ceiling low floor is increasing users concentration, but the degree of freedom is lost. So to cover the mobility in Uni-Cub.
24	13th	Uni-Cub converts human motion into communication.
25	14th	Communication using body trunk motion
26	14th	Converts the movement to the media. And Uni-Cub users communicate by this media.
27	14th	Conveying the emotion by the movement in the business scene, to support the communication.



(a) The degree of divergence of ideas



(b) The history of the degree of divergence

Figure 6. The results of the degree of divergence analysis

3.3 The system architecture results

The 27 ideas explained in Table 3 were investigated in terms of the architecture of the idea-creation system based on three viewpoints: physical, functional, and purpose. The results are summarized in Table 4 and the history of viewpoint movement is indicated in Figure 7. The idea-creation system has 24 physical, 21 functional, and 9 purpose viewpoints. It was found that the ideas generated within the physical and functional viewpoints were from ideas No. 1–8, and members reached the purpose viewpoint for the first time at idea No. 9. After idea No. 16, team members started to generate ideas through more frequent hierarchy movements (among viewpoints).

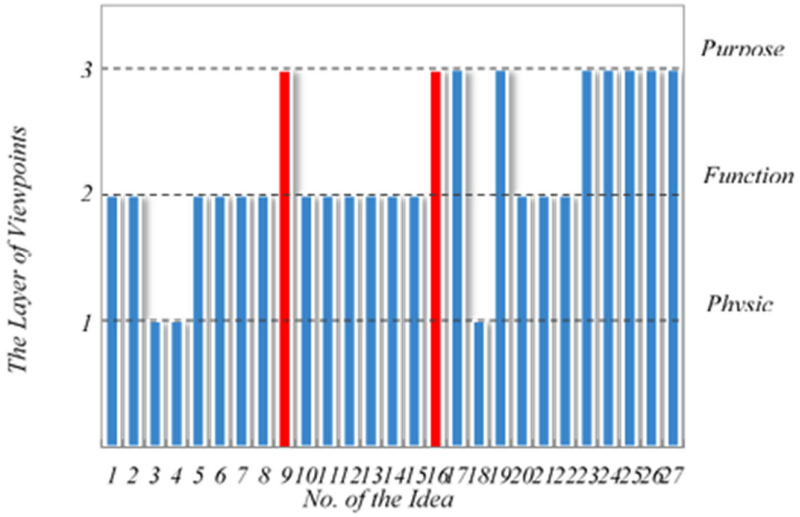


Figure 7. The history of viewpoint movement

Table 4. The ideas and their structure

No	Physical	Functional	Purpose	Viewpoint layer
1	Communication System	Communication		*2*
2	Healthcare Application	Healthcare		*2*
3	Huge Facility			1

4	Creative Space			1
5	Emotional Awareness System	Emotional Awareness		*2*
6	Concierge System	Concierge		*2*
7	Personal ID	Personalize		2
8	Storage Space	Storage		2
9			Change User Mind	3
10	Storage	Memory		2
11		Body Trunk Training		2
12	Dog	Operation for Dog		2
13	Secretary System	Secretary		2
14	Communication System・ Emotional Awareness System	Communication/Emotional Awareness		2
15	The Operation Mode is by the Human Feelings	Mode Change/Emotional Awareness		2
16	Rehabilitation Facilities/Rehabilitation System	Affective change	Rehabilitate the User	3
17	Half Floor (Low-ceilinged building)		Changing the Concept of the Building	3
18	Space for U-C only			1
19			User Will Want to Move	3
20	Emotional Awareness System	Converts Human Motion to Value		2
21	Feelings Conversion Application	Convert Unconscious Behavior to Explicit Knowledge		2
22	Light/Sound/Feelings Conversion Application	Convert Feeling to Media		2
23	Half Floor (Low-ceilinged building)		Raise the Work Efficiency	3
24	Feelings Conversion Application	Convert Unconscious Behavior to Explicit Knowledge	Converts User's Motion into Communication	3
25	Body Trunk Motion Conversion Application	Convert Body Trunk Motion to Explicit Knowledge	Converts User's Motion into Communication	3
26	Feelings Conversion Application/Communication System	Convert Unconscious Behavior to Explicit Knowledge/Communication	Create New Communication	3
27	Motion Data Recording and e-mail	Motion Data Recording	Create New Business Communication	3

3.4 The factor analysis of breakthrough results

As the final step of the idea-space systems analysis, the elements of the idea-creation system for catalyzing breakthroughs were investigated by combining the two results obtained from the degree of divergence and the systems architecture analyses. The relationship between the degree of divergence and the hierarchy movements in the idea system is shown in Figure 8 (the idea numbers are from Table 3). From these results, it is clearly shown that the degree of divergence and hierarchy movements are positively correlated. In other words, the degree of idea divergence would increase in cases where ideas are generated at a higher hierarchy (more movements among viewpoints). Looking at the divergence results, the degree of divergence became larger over the latter half of the workshop period. Additionally, grouping the workshop into three segments, ideas No. 1 to 8, No. 9 to 17, and No. 18 to the end, the degree of divergence gradually becomes larger. According to the analysis results of the hierarchy movements for each period shown in Figure 8, these clearly indicate that the hierarchy movements occurred only between the physical and functional viewpoints in the first period (No. 1 to 8), and between the functional and purpose viewpoints in the second period (No. 9 to 17). Furthermore, team members generated ideas through more frequent hierarchy movements between physical and purpose viewpoints.

Based on the above analyses, it is suggested that the degree of idea divergence created by shifting or adding physical or functional viewpoints will not generate a lot of change. Additionally, the divergence of ideas created only within purpose and functional viewpoints also have limits. On the other hand, idea generation using frequent hierarchy movements from physical to purpose viewpoints leads to the creation of new concepts. The hierarchy movements or changing viewpoints for idea creation is required for catalyzing idea breakthroughs.

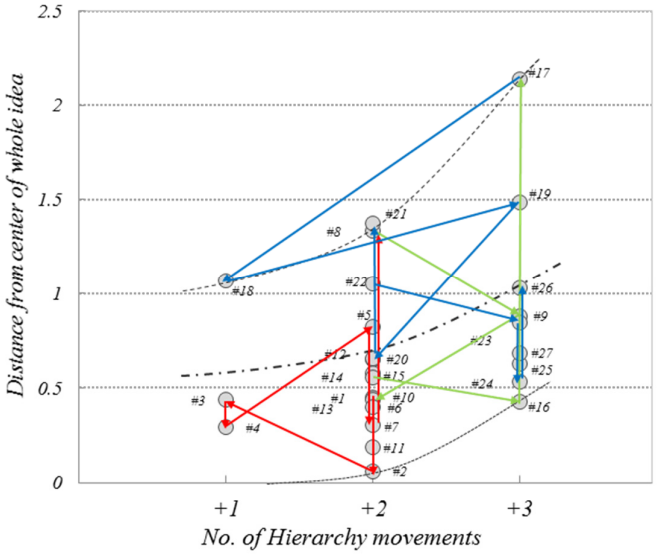


Figure 8. The degree of divergence and hierarchy movement

4. Conclusions

In this study, in order to establish a methodology of consecutive idea creation, this study focused on the elements for catalyzing breakthroughs. The mechanism of a creative breakthrough has been analyzed using proposed idea-space systems analysis. All the ideas were sampled over 15 weeks as part of the design project at Keio SDM. The degree of idea divergence was measured from correspondence analysis and the hierarchy movements (i.e., the number of changes among the viewpoints) from the systems analysis. Finally, by combining the two results obtained from these analyses, the elements for catalyzing breakthroughs were studied. From the results, the following conclusions can be drawn:

1. In this study, about 60% of the ideas were created within the first one-third of the whole period of the workshop. Idea creation faces difficult to generate new ideas the second one-third. It shows the team got stuck on creating idea. At the beginning of the workshop, team stereotypes were not yet formed among the team members, and new ideas were generated more easily by member diversity. However, the process of collecting information and generating ideas eventually caused the members to become unable to create new ideas.
2. The quantity of idea is the largest, however the degree of diversity is the lowest within the first one-third of the workshop. On the other hand, the degree of diversity became the largest at the final one-third of the period. The relationship between the quantity of generating idea and the degree of diversity have negative correlation.
3. Looking at the degree of idea divergence analysis, the average degree of divergence became larger over the latter half of the workshop period. Additionally, it appeared that the distance from the center of all the ideas rapidly becomes larger twice during the whole period.
4. From the analysis of the systems architecture, at the beginning of the workshop the ideas generated were within the physical and functional viewpoints, and team members gradually began to generate ideas by more frequent hierarchy movements.
5. According to the relationship between the degree of idea divergence and the hierarchy movements of the idea system, it was shown that the degree of idea divergence would increase in cases where ideas were generated at higher hierarchy. The conclusion from this

is that idea generation using frequent hierarchy movements among physical and operational viewpoints leads to the creation of newer idea concepts.

From the study of the idea-creation system using idea-space system analysis, it is concluded that to catalyze breakthroughs, the changing viewpoints are required. In further work on systems analysis for catalyzing breakthroughs, we will conduct research using ISSA to apply more samples, including other elements, members' dynamics, applied methods, prototypes etc..

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