

Products Designed on Scenario Maps using Pictorial KeyGraph

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Abstract: - We developed a method of teamwork for a product design in a real manufacturing company, where Pictorial KeyGraph aids in the creative consensus of team mates. In Pictorial KeyGraph, photographs of real entities corresponding to incomprehensible items in given data are embedded to the visual result of KeyGraph applied to their business reports, by users with tacit and explicit expertise in the real world of business on the way of the communication for designing a product. In their communications, novel and practical scenarios of product behaviours were extracted, and 5 new patents have been applied. Behind this success, we found evidences that the team members tend to combine established concepts via rare words in creative designing: First pay attention to popular concepts in their business reports, appearing as *islands* in KeyGraph. Then, they calm down to speak less, and finally produce new scenarios by connecting islands via items lying between islands in KeyGraph.

Key-Words: - Data Visualization, Pictorial KeyGraph, Scenario Map, Design, Creativity

1 Introduction

In manufacturing companies, it is expected the members develop new products responding to users' requirements. For this purpose, they create scenarios of the behaviours of forthcoming products and users. Here a scenario means a story in which a designed product/service is used. Designing a scenario is being regarded as essential as designing the service or the final product [1, 2, 3].

Previously, various technologies came to assist *chance discovery* [4], which is defined as to detect, understand, and use events that are significant for a decision. As shown in the literature [4, 5], the process of chance discovery and scenario design are in a mutually-involving relationship. In chance discovery, tools for visualizing the relation among events/items based on data, such as KeyGraph [6], has been introduced. By looking at the diagram, user is supposed to understand the meaningful sequence of events, by connecting closely located items. Some successful cases have been presented [7,8] in the domain of marketing, e.g., marketers in a textile manufacturing company achieved consensus to duplicate the production

quantity of a new products, by creating the scenario of product's behaviours in the market. They increased the sales of products, as a result.

However, a critical problem has been remaining if user intends to apply the method to design and development. That is, the working members of a manufacturing company are born and bred in different contexts. For example, engineers and designers are graduated from engineering school, and marketers may be from business or management schools. These people should talk for developing a new product, which is different from the marketers' communication in [7]. Thus, the vocabulary gap among these people causes a deadlock, i.e., the creative ideas of developers and designers can not contribute to the corporate decision. In turn, the proposals from marketers do not move designers or developers. Even if there are technical sales people good at talking both with designers and customers, their words may not easy for marketing people or management staffs, due to the vocabulary gaps. In this paper, we propose and validate a method to aid the cross-disciplinary communication to achieve a decision of a product design.

2 Summaries of the Problem and the Solution Method

In this paper, let us take an example of a team, running under the mission to create new functions or products of linear Charge Couple Device (CCD) surface inspection system. The designed system should certainly survive in the competition in the market, by satisfying the requirement of customers.

Here we can point out a critical issue: The system to be produced here is a complex machine, to be dealt with by highly trained technicians in CCD surface inspection system manufacturing companies. Such users of the CCD surface inspection system are skilled engineers, as well as the designers, developing technicians, and the technical sales staffs. Although technical sales people collected and brought customers' reports, those reports were the children of technical experts – all written in specific engineering terms. Even though the reports included call (free text on the communication between customers and the technical sales people) reports and test reports (experiments of system for customers' sample), no new and practical ideas for product innovations have been extracted after all.

To this problem, we adopted the following procedure. Here the tool is KeyGraph, with a new function to embed pictures of real entities corresponding to items (i.e., words) in the customers report. This function is used in 2-2).

[The Design Communication with Pictorial KeyGraph]

- 1) Visualized the textual dataset D , obtained by putting customer reports in one, by KeyGraph.
- 2) Do communication about considerable scenarios with looking at the graph shown in 1). This communication goes as:
 - 2-1) Each participant presents a scenario about the product behaviours.
 - 2-2) If there is an item on KeyGraph, which is hard to understand, then a participant may request other participants to embed a picture of the corresponding entity.
 - 2-3) The moderator may control participants so that the utterances do not be biased to a few members.

- 3) After a fixed time length of communication, the moderator stops and select the most feasible scenarios from the criteria of the cost of development and the expected sales.

This method may seem to be a minor change of previous method of chance discovery in business as in [7, 8]. However, we expected that the simple revision with showing pictures for unknown words realizes a significant breakthrough. The advantage is three fold: First, the vocabulary gap is filled by the pictures. Second, the deeper level gap that is the difference in the concerns of team mates is also filled, by visualizing the interestingness of the most uncertain components of the diagram. It has been pointed out that uncertain information triggers a favourable design process [10], but this stands only if the collaborators share a going concern with the development. Third, the pictures are easier than words for the user to imagine the real scenes of product behaviours.

In the reminder, we go as follows. In Section 3, the outline of KeyGraph is introduced (reader is referred to [6] for details). Then, Pictorial KeyGraph is shown with showing the operation on Polaris. Then, in Section 4, we show how we applied this tool to the data-based design communication. Finally, in Section 5 we show the real-world business result we obtained by this method and the process of the participants though. This evaluation is purely subjective and uncontrolled, in that we see the effects of the presented method on human's creativity in the real process of design, not on any precision/accuracy measures. This is an ideal way of evaluation in this study, because our goal is to resolve the communication gap caused by the participants' difference in their expertise. By solving this severe human-factor problem, we find significant creativity apparently caused by the pictures on Pictorial KeyGraph.

3 KeyGraph and Pictorial KeyGraph

Pictorial KeyGraph is an extension of KeyGraph [6], with embedding pictures of real entities in the data. Let us show the outline of KeyGraph first, and then of Pictorial KeyGraph.

3.1 The Basic KeyGraph

KeyGraph is a tool for visualizing the map of item relations in the dataset, in order to aid in the process of chance discovery. By visualizing the map where the items appear connected in a graph, one can see the overview of the target environment. Suppose a dataset D is given, describing an event-sequence sorted by time, where each line ends at the moment of a major change. For example, let a data set D be:

$$\begin{aligned}
 D &= && a1, a2, a4, a5 \dots \\
 &&& a4, a5, a3, \dots \\
 &&& a1, a2, a4, a5, \dots, a10. \\
 &&& a1, a2, a4, \dots, \dots, a10. \\
 &&& \dots
 \end{aligned}
 \tag{1}$$

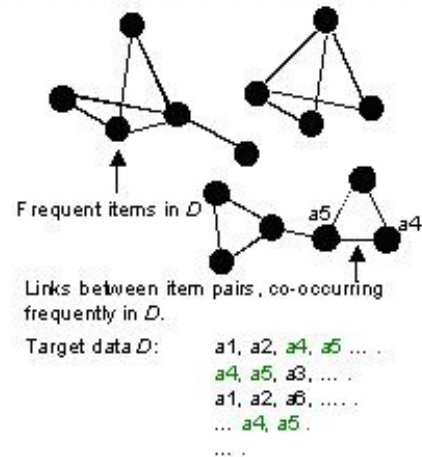
For data D , KeyGraph runs as follows, where M_0 , M_1 , M_2 are fixed by user:

KeyGraph-1: Clusters of frequent items (events among the M_0 most frequent in D) are made, by connecting the M_1 highest co-occurrence pairs. Each cluster is called an *island*. Items in islands (e.g., the word “market” in Eq. (2)) are depicted with black nodes, and each pair of these items occurring often in the same line is linked via a solid line. As a result, each connected graph forms an island, implying a common context underlying the belonging items. This step is realized as in (1) and (2) of Fig.1, to cut weak links and form meaningful islands corresponding to existing concepts.

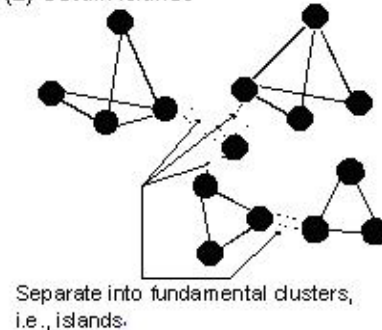
KeyGraph-2: Items which may not be as frequent as the nodes in islands, but whose co-occurrence with more than one islands are among the M_2 highest item-island co-occurrence, e.g., “restructuring” in Eq. (2), are obtained as *hubs*. Here, the co-occurrence of item X and an island Y is defined by the occurrence frequency of X and items in Y in the same sentence. A path of links connecting islands via hubs is called a *bridge*. If a hub is rarer than the black nodes in islands, it is depicted in a different colour (e.g. red). We can regard such a new hub as a candidate of a *chance*, i.e., an item significant with respect to the structure of item-relations. See Fig.1 (3).

As a result, the output of KeyGraph as shown in (3) of Fig.1 includes islands and bridges, and this is expected to work as a scenario map. In the example of Fig.2, for the text in Eq. (2), island (1) means the context where the market is shrinking, and island (2) shows the context of a target company. The bridge “restructuring” shows the company may introduce restructuring, e.g. firing employees, for surviving the crisis.

(1) Obtain the co-occurrence network



(2) Obtain islands



(3) Obtain bridges, on which chances may exist

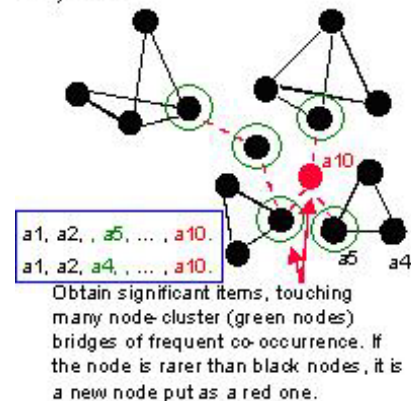


Fig.1 The procedure of KeyGraph

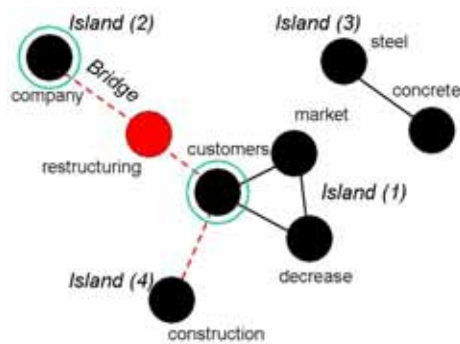


Fig.2 KeyGraph for D in Eq. (2). Each island includes event-set {customers, decrease, market}, {steel, concrete}, {company}, etc. The double-circled node and the red (“restructuring”) node show a frequent word and a rare word respectively, which forms hubs of bridges.

“Restructuring” might be rare in the communication of the company staffs, but this expresses the concern of the employees about restructuring in the near future.

$D =$ “

- Speaker A: In the market of general construction, customers decreased.
- Speaker B: Yes... My company build from concrete and steel, is in this bad trend.
- Speaker C: This state of the market induces a further decrease of customers. We have to introduce restructuring, for satisfying customers.
- Speaker B: I agree. Then the company can reduce the production cost of concrete and steel. And, the price for the construction...
- Speaker D: That weakens the company.” (2)

KeyGraph is a tool for what we call *chance discovery*, i.e., the discovery of events significant for decision making. The user is supposed to first see the islands to understand the most basic concepts in the target world. Then, the user might find some bridges between the islands to find novel scenarios that are a sequential appearance of islands via rare events as depicted by the red bridging nodes.

In the case of reference [7], KeyGraph applied to the customers’ preference data of textile products. Although the graph was complex, professional marketing staffs of the textile development & sales company discovered a “chance” product on the graph. In this case, they physically embedded real textile pieces corresponding to the node in the output graph. As a result, they smoothly reached a discovery of a promising textile, which bridge

basic (established) customers to form a proposing market of their products.



Fig.3 The usage of Pictorial KeyGraph (on our original software named Polaris [9]) Pictorial KeyGraph

3.2 Pictorial KeyGraph

Pictorial KeyGraph succeeds the method to embed realistic images onto the graph, after the experience of the textile company. Here, we introduce Pictorial KeyGraph, where nodes are replaced by pictures of corresponding real entities in data set D . This replacement has been executed by user’s dragging picture icons, from the PC desktop to the output window of KeyGraph (See Fig.3).

4 Application of KeyGraph to Product End-User Reports

4.1. Preliminary study and tasks

We executed preliminary study based on customer call reports and test reports. The reports were written in free text format by technical sales people, on new functions and new products related to linear CCD surface inspection system. The aim of these reports was to detect defects (scratches on the web film surface as in Fig.4), as required by customers, on their products by the inspection system.

It was, however, neither possible for all of technical sales people to interpret nor to create scenarios from KeyGraph without pictures, after processing all customer call reports and test reports by KeyGraph working on the Polaris platform [10].

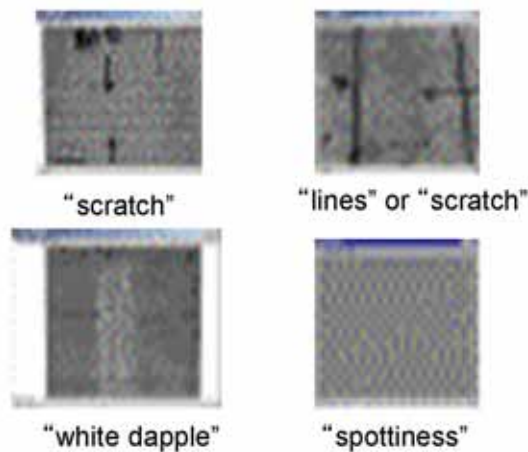


Fig. 4 Defects on the surface of CCD.

After this preliminary study, we found three major tasks to be settled. Firstly, 20 groups of defects, which include 64 defect categories, had some names given by the customers, who are experts of CCD production. However, the meanings of those names were neither identified by technical sales people, nor by the managing executive of technical sales section. Secondly, the large majority of these names came to be located as red nodes in KeyGraph, i.e., as bridges. Lastly, the meanings of the defect names were ambiguous: Same names were assigned for seemingly different defects, in the customer call reports and test reports.

4.2 Application of Pictorial KeyGraph to redesigning CCD surface inspection systems

We executed the following procedure.

1. Prepare photographs of all defects for 20 groups, of 64 categories, and identify the names used for these defects among the subject customers.
2. Create a graph, with Pictorial KeyGraph, embedding above photographs of defects to nodes for corresponding names (mainly red nodes on KeyGraph). See Figure 5.
3. Separate customer call reports and test reports into each customer basis.

On the way of this procedure, the common opinions of subjects agreed it came out to be much easier to identify names of defects commonly among them, and understand the relation with defects as bridges, among islands corresponding to

topics on camera, image processing software, lighting, etc.

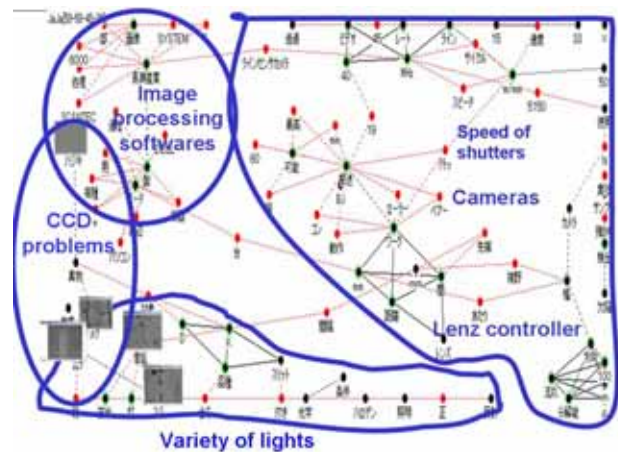


Fig. 5 a result of Pictorial KeyGraph for the reports from customers, i.e., the end users of CCD surface defect inspector.

4.3 Experimental conditions and process

In this study, (1) sales manager managing the sales of the system, (2) experienced technical sales people with more than 10 years experience for technical sales, and (3) inexperienced technical sales people of experience less than 3 years, were chosen, 6 subjects in total. This number may look small, but is the maximum number of experts we can collect. It is clearly meaningless to have non-experts of CCD surface, considering our goal to obtain novel business scenarios.

To these subjects, 16 graphs were shown one by one. Each scenario was created through group discussion among subjects. That is, they uttered scenarios, and threw objections if any to presented scenarios, for each graph. And, when all subject participants in the group agreed with a scenario, the scenario was recorded. Thus, a number of scenarios came out as a data set in time series.

5. Experimental Results

5.1. Classification of extracted scenarios

During the discussion, 104 scenarios were obtained sequentially. These 104 scenarios

could be classified into 85 about the present design and 19 about future designs, respectively, of CCD surface inspection system.

For example, the following are two of the 19 scenarios for the future designs.

1. *Use Line Sensor Camera N5150Hs with 50mm lens, of which the resolution and the video rate are 100 micron toward width and length and 40 MHz. This is for inspecting unevenness, line, sputter and drop out, etc., which our customers require.*
2. *Use fluorescent lamp in regular reflection and Halogen lamp with slit in transmission, by changing the width of slit. This change should be done according to the category of the defect.*

5.2. The roles of islands (black nodes) and bridges (red nodes)

We took the correlation matrix as in Table 1 to show the relations between the number of characters, words, and the words corresponding to black nodes in the graph the subjects saw, per scenario among the 104 presented.

As a result, the number of characters of each of the 85 present-design scenarios had a significant correlation (0.800++) with the number of words for the black nodes (Table 1). However, this tendency was not found for the 19 future-design scenarios. Neither the number of characters in each of 85 present situations nor in each of 19 future proposals showed correlation with the number of words corresponding to red nodes in each scenario.

Table1: Correlation Matrix for the 85 present-design scenarios

Variance	No. Character	No. Black node	No. Red node
No. Character	1.000	.800++	.529
No. Black node	.800++	1.000	.293
No. Red node	.529	.293	1.000

The analysis of temporal variance among the number of characters in each scenario and of words for the black/red nodes contained in each scenario, among those extracted from the 16 graphs obtained by Pictorial KeyGraph, was executed. The following features were common to 10 (of the 16) graphs, that were all the graphs from which the 19 future-design scenarios were extracted (100%), according to the curves in Figure 6.

1. The scenarios mostly correspond to present designs. Then, just before the appearance of a future-design scenario, the number of characters per scenario decreases.
2. The number of words for red nodes per scenario decreases once, a few scenarios before the appearance of a future-design scenario.

In addition, we observed the following feature in 8 of the 10 graphs (80%).

3. The number of words for red nodes per scenario increases, just on/after extracting a future proposal.

Based on these observations, we hypothesized that new scenarios emerge from the combination of established islands, via the awareness of bridging red nodes (See Figure 7).

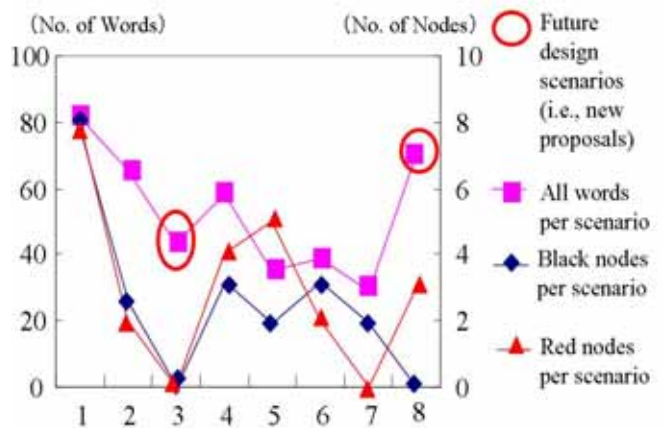


Fig. 6 The temporal variance of the numbers of words and red/black nodes, and the timing of the appearance of future-design scenarios.

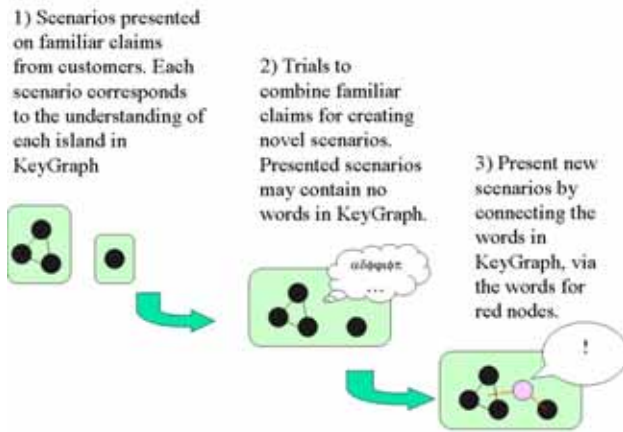


Fig. 7 A hypothetical model of scenario emergence: The participants pay attention to the islands as the building blocks, and the emerging scenario converge into a well-organized description where the blocks are combined to.

If this hypothesis stands, it gives us useful implication: For example, we can improve the way of use of KeyGraph as follows: First show the black nodes and black links, i.e., only the islands, until the user thinks over for creating new scenarios. Then, show the red nodes and red links which may play a role as a bridge for expressing new ideas about the future scenarios.

In order to validate this hypothesis, we investigated the data of presented scenarios into more details. First, we counted the number of words corresponding to red nodes per present-design scenario, and per future-design scenario. As a result:

1. The number of present-design scenarios containing red nodes, appearing one scenario before a future-design: 16 (of 19) scenarios
2. The number of present-design scenarios *not* containing red nodes, appearing one scenario before a future-design: 3 scenarios
3. The number of future-design scenarios containing red nodes: 10 scenarios

Thus, we can say that a present-design scenario, presented when the participants are close to creating a future-design scenario, tends to be created referring to the words for red nodes. When the participants go into the phase to present future scenarios, more than half of scenarios are created referring to red nodes.

Then, we checked the topics of future-design scenarios and present-design scenarios, appearing just before and after the appearance of future-design scenarios. Here a topic means the theme discussed, corresponding to the component of the product they considered to improve. For example, “about camera in the CCD surface inspection system” “about image processing software,” and so on, was the topics.

The results were as follows:

1. The topics of the future-design scenarios were the same as of present-design scenarios just *before* the future-design: 12 (of 19) scenarios.
2. The topics of the future-design scenarios were the same as of present-design scenarios just *after* the future-design: 2 (of 12: the other 7 future-design scenarios appeared at the last of discussion, so no scenarios after the 7 could be counted) scenarios.

The same topic has been discussed by examinees mainly just before “Future proposal”. But the topic was changed suddenly to another one on or just after “Future proposal”

5.3 Fruits in real business

As a result of the process above, some successes in business were obtained from the scenarios that emerged as future-design scenarios. For example, we adopted the scenario below, one of the future-design scenarios, for developing a new product.

“Develop the marking system and marking Ink to draw marks near by defects such as Scratch, Chink, Pustule, Black dot, White dapple and foreign body after detecting them on the surface of film.”

Here, the manufacturer of CCD surface inspector executed an experimental production of the marking system with marking ink pen. This machine draws marks near by defects on the surface of films after detecting them by our linear CCD surface defect inspection system. This product reflected the five patents below we really applied, which correspond to sub-goals for realizing chosen the scenario above. (Patent application 1) Method for slitting process

(Patent application 2) Marking equipment with shutter for the marking pen (Patent application 3) A location marking method (Patent application 4) Solenoid driving method for the marking pen (Patent application 5) Marking method to locate defect between upper and lower side.

4 Conclusion

We developed a method of teamwork for a product design in a real manufacturing company, where Pictorial KeyGraph aids in the creative consensus of team mates. In Pictorial KeyGraph, photographs of real entities corresponding to incomprehensible items in given data are embedded to the visual result of KeyGraph applied to their business reports, by users with tacit and explicit expertise in the real world of business on the way of the communication for designing a product. In their communications, novel and practical scenarios of product behaviours were extracted, and 5 new patents have been applied. The CCD inspection system developed and sold from this company is the current most well accepted by users (customers), even though the company had been suffering from slow pace of inventions.

Behind this success, we found evidences that the team members tend to combine established concepts via rare words in creative designing. Conceptually, such a mechanism of creativity has been considered in the literature [11], and has been applied to realizing creative communication environment [12, 13]. However, this paper still presents a new finding. That is, the visualization of KeyGraph should be bottom-up, as shown in Figure 7 in 5.2: Show the islands first, until the user thinks over for creating new scenarios and then show the bridges which may aid in presenting new ideas about the future scenarios. This finding presents supportive evidence to the instructive studies in design communication, where good questions make the trigger to good designs [13]. The uncertain information as words in the red nodes has been said to be helpful to creative design (see [10]), but presents even a stronger hint when given at the better timing, i.e., when the designer is asking for a new hint for creating a design.

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