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Ohsawa · Tsumoto

Chance Discoveries in Real World Decision Making

Data-based Interaction of Human Intelligence and Artificial Intelligence

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Chance Discovery: The Current States of Art

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1 Introduction: Scenarios and Chances in the Basis of Decisions

As defined in [18],a *chance* in chance discovery means to understand an unnoticed event/situation which can be (uncertain, but) significant for making a decision. Associating the event with the appearance of a product or a service, customers seek a valuable event, i.e., the appearance of a product/service significant for his/her decision to improve daily life. Associating the event with a message from a customer, people in the side of business should look at a valuable event, i.e., a message significant for the decision to improve the service.

Chance discovery is an essential basic research area applicable to all kinds of business. The above definition of a chance may have sounded counter-intuitive for reader thinking about an accident or uncertainty, say events occurring *by chance*. To such an opinion, we have been asserting chance discovery means the discovery *of* chance, not *by* chance. However, according to the recent progress of studies on the methods of chance discovery, the relevance between discovery *of* chance and discovery *by* chance came to be more positively recognized. That is, a chance defined as an event significant for decision making has all the natures of a chance in the phrase "by chance," i.e. (1) uncertainty, (2) accident (3) probability, if we introduce scenario-based thoughts about chance discovery, and these can all be put into a power of survival.

Note here, that a decision means to choose one from multiple possible scenarios of future events and actions, so there is "uncertainty" in (1), in the future scenarios where chance discovery is desired. In other words, uncertainty can be the motivation to decide something. Therefore, "probability" in (3) rather than True/False may become an appropriate measure of the justification of a scenario. An "accident" of (2) implies uncertainty to lead to an opportunity or to a risk, relying on the future scenario.

In general, a scenario is a time series of events/states to occur under a certain context. And, a chance can be regarded as the cross of multiple scenarios.

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For example, suppose a customer of a drug store buys a number of items in series, a few items per month. He should do this because he has a certain persistent disease. In this case, a remedy of the disease suggested from his doctor is the context shared over the event-sequence, where an event is this patient's purchase of a set of drugs. This event-sequence is a scenario under the context proposed by the doctor. However, the patient may hear about a new drug, and begin to buy it to change the context, from the remedy he followed so far to a new remedy to seep up his cure. In other words, the patient introduces a new scenario. After a month, his doctor gets upset hearing this change due to the patient's ignorance about the risk of the new drug. The doctor urgently introduces a powerful method to overcome all the by-effects of the risky new drug - changing to the third scenario.

In this example, we find two "chances" in the three scenarios. The first chance is the information about the new drug which changed from the first remedy scenario to the second, riskier one. Then the doctor's surprise came to be the second chance to turn to the third scenario. Under the definition of "chance," i.e., an event or a situation significant for decision making, a chance occurs at the cross point of multiple scenarios as in the example because a decision is to select one scenario in the future. Generally speaking, a set of alternative scenarios form a basis of decision making, in domains where the choice of a sequence of events affects the future significantly. Based on this idea, the methods of chance discovery have been making successful contributions to science and business domains [1].

Now let us stand on the position of a surgeon looking at the time series of symptoms during the progress of an individual patient's disease. The surgeon should make appropriate actions for curing this patient, at appropriate times. If he does so, the patient's disease may be cured. However, otherwise the patient's health condition might be worsened radically. The problem here can be described as choosing one from multiple scenarios. For example, suppose states 4 and 5 in Eq. (1) mean two opposite situations.

$$\begin{aligned}\text{Scenario } 1 &= \{\text{state } 0- > \text{state } 1- > \text{state } 2- > \text{state } 3- > \\ &\qquad \text{state } 4 \text{ (a normal condition)}\}. \\ \text{Scenario } 2 &= \{\text{state } 4- > \text{state } 5- > \text{state } 6 \text{ (a fatal condition)}\}. \qquad (1)\end{aligned}$$

Each event-sequence in Eq. (1) is called a *scenario* if the events in it share some common context. For example, Scenario 1 is a scenario in the context of cure, and Scenario 2 is a scenario in the context of disease progress. Here, suppose there is a hidden state 11, which may come shortly after or before state 2 and state 5. The surgeon should choose an effective action at the time of state 2, in order to turn this patient to state 3 and state 4 rather than to state 5, if possible. Such a state as state 2, essential for making a decision, is a *chance* in this case.

Detecting an event at a crossover point among multiple scenarios, as state 2 above, and selecting the scenario going through such a cross point means a chance discovery. In general, the meaning of a scenario with an explanatory context is easier to understand than an event shown alone. In the example of the two scenarios above, the scenario leading to cure is apparently better than the other scenario leading to a fatal condition. However, the meaning of chance events, which occurs on the bridge from a normal scenario to a fatal scenario, i.e., state 2, state 11, and state 5 in Fig. 1, are hard to understand if they are shown independently of more familiar events. For example, if you are a doctor and find polyp is in a patient's stomach, it would be hard to decide to cut it away or to do nothing else than leaving it at the current position. On the other hand, suppose you find the patient is at the turning point of two scenarios - in one, the polyp will turn larger and gets worsened. In the other, the polyp will be cut away and the patient will be cured. Having such scenarios, you can easily choose the latter choice.

Consequently, an event should be regarded as a valuable chance if the difference of the merits of scenarios including the event is large, and this difference is a measure of the utility of the chance. Discovering a chance and taking it into consideration is required for making useful scenarios, and proposing a number of scenarios even if some are useless is desired in advance for realizing chance discovery. For realizing these understandings, visualizing the scenario map showing the relations between states as in Fig. 1 is expected to be useful. Here, let us call each familiar scenario, such as Scenario 1 or Scenario 2 , an *island*. And, let us call the link between islands a *bridge*. In chance discovery, the problem is to have the user obtain bridges between islands, in order

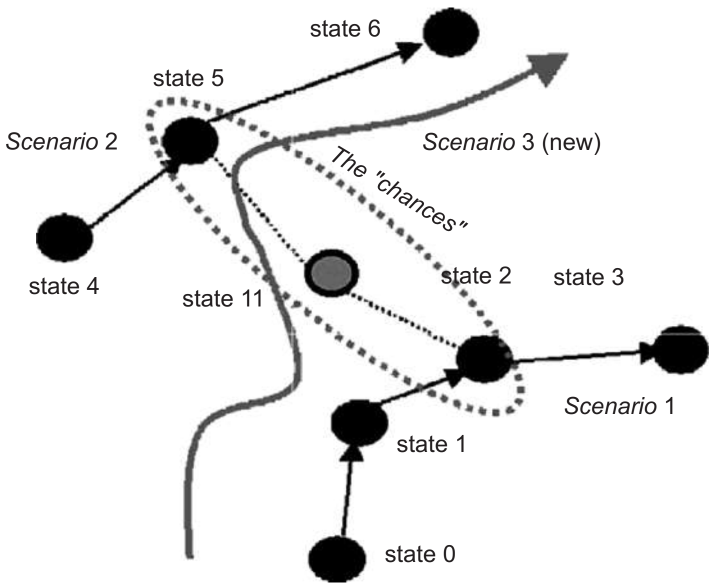

Fig. 1. A chance existing at the cross point of scenarios. The scenario in the thick arrows emerged from Scenario 1 and Scenario 2.

to explain the meaning of the connections among islands via bridges, as a scenario expressed in understandable language.

The research goal of chance discovery has been to enable to choose useful scenarios at the time one should do so, i.e., at the time of a chance, and to accelerate the decision to act on the optimal scenario.

2 Scenario “Emergence” in the Mind of Experts

In the term “scenario development”, a scenario may sound like something to be “developed” by human(s) who consciously rules the process of making a scenario. However, valuable scenarios really “emerge” by unconscious interaction of humans and their environment. This occurs like the event 2 appears for itself and all the events in Fig. 1 self-organizes a complex new scenario as the think curved arrow.

For example, a *scenario workshop* developed by the Danish Board of Technology [26] starts from scenarios preset by writers, then experts in the domain relevant to the preset scenarios discuss to improve the scenarios. The discussants write down their opinions during the workshop, but it is rare they notice all the reasons why those opinions came out and why the scenarios have got obtained finally. Rather, new ideas emerge by the self-organizing interactions of particles of ideas from participants. As Montero writes in Chapter 3, self-organization is in the essence of scenario emergence.

This process of scenario workshop can be compared with the KJ (Kawakita Jiro) method, the method in the origin of creation aid, where participants write down their initial ideas on KJ cards and arrange the cards in a 2D-space in co-working for finding good plans. Here, the idea on each card reflects the future scenario in a participants’ mind. The new combination of proposed scenarios, made during the arrangement and the rearrangements of KJ cards, helps the emergence of new valuable scenarios, putting in our terminology. In some design processes, on the other hand, it has been pointed out that ambiguous information can trigger creation [6]. The common points among the scenario “workshop”, the “combination” of ideas in KJ method, and the “ambiguity” of the information to a designer is that scenarios presented from the viewpoint of each participant’s environment are bridged via ambiguous pieces of information about different mental worlds they attend. From these bridges, each participant recognizes situations or events which may work as “chances” to import others’ scenarios to get combined with one’s own. This can be extended to other domains than designing. In the example of Eq. (1), a surgeon who almost gave up because he guessed his patient is in Scenario 2, may obtain a new hope in Scenario 1 proposed by his colleague who noticed that state 2 is bridging to both scenarios - only if it is still before or at the time of state 2. Here, state 2 is uncertain in that its future can potentially go in two directions, and this uncertainty can make a chance, an opportunity not only a risk.

3 The Process of Chance Discovery

Note that the difference of chance discovery and data mining is that chance discovery aims at obtaining the chances at the cross points of meaningful scenarios, whereas data mining obtains meaningful patterns in the data. If a method of data mining can obtain such pattern as "(state 1 -> state 2) -> state 11 -> (state 5 -> state 6)" in Fig. 1, where the cross of Scenario 1 and Scenario 2 is included, then we can say such a tool can be *used for* chance discovery. However, in general, a data mining tool which can obtain such a complex pattern tends to obtain a huge number of other long patterns, and finally human (user) should choose the most meaningful pattern. As a result, in chance discovery, a critical thing to consider is human's thoughts for choosing meaningful scenarios, and a data mining tool can be a powerful support for the thinking human(s).

If co-workers in a company section are discussing in order to choose a future scenario of business, their empathy with a proposed scenario is necessary for taking the scenario into their new actions. This empathy leads to not only logical thinking and agreement, but also the mutual understanding of each other's stand points from the level of emotion. By the coupling of scenarios under participants' empathy with scenarios and the underlying daily lives of proposers, a scenario meaningful for the team working tends to emerge. We call this a scenario emergence in communication. And, a data mining tool to be mentioned hereafter which has a function to visualize a scenario map as in Fig. 1 can support the coupling, the creation, and the choice of scenarios. As well, tools for predicting rare events [4, 8, 9] plays a significant role in the process of chance discovery.

Suppose we have two scenarios, Scenario 1 and Scenario 2 in Fig. 1, a new scenario may emerge as in the thick arrows. Here, the scenarios make a crossover and generate a new one, like the crossover of chromosomes generating a new chromosome. It is easy to write this way. However, we should stop here and think carefully. We should imagine a simple but real setting in business to consider the difficulties to communicate having empathy with the proposed scenarios and with the underlying daily lives of participants. Let us take an example of a chain of sushi-bars. Traditional sushi-bars were not big companies. However, the recent outbreak of low-price sushi-bars made a number of sushi-bar chain companies. A chain may have tens of sushi-bars all over Japan. In this situation, a chain involves sushi-masters, the head of each sushi-bar, central managers controlling a number of sushi-bars, advertisement and customer-relationship sections, etc. From these staffs, let us pick (a) 10 sushi masters from two local sushi-bars (five from each), and (b) five members of the customer-relation section of the company. The problem is whether or not these 15 staffs can find a coherent decision, i.e., consensus, in developing a new sushi item.

Sushi-master 1 in bar A) I often see customers eating O-toro and Chu-toro. Both items are of oily meat of tuna, so I think we should make original oily tuna items.

Sushi-master 2 in bar B) Your customers are rich, because your place is in a high-class area Ginza. Our customers are students, so we have to increase squids and sardines.

Sushi-master 3 in bar B) No, no! Students take O-toro if we serve in our price.

Sushi-master 1 in bar A) Why don't you think of Ise-ebi (king robster)? This is still rare, but the customers look very happy when they eat one.

Sushi-master 2 in bar B) Umm⋯ You do not know students ⋯ Students can not even imagine the taste of Ise-ebi. How can they order Ise-ebi when they can not imagine its taste?

Customers relation staff 1) Why don't you propose the customers to try Ise-ebi with any explanation about its taste, if you think they do not know it?

Sushi-master 3 in bar B) Students are very greedy ⋯ We are too busy making what they order. How can we explain about Ise-ebi?

Customers relation staff 2) We may have to make a pamphlet of new items, including Ise-ebi, to inform customers about their tastes.

Sushi-master 3 in bar B) No! You cannot move their interest with such papers! They do not read before eating!

As found here, a difficulty lies in finding a consensus in scenario communications. The reason is that the participants have different background domains, and it is hard to present in advance the details of all expertise to be used in their own thoughts for communication. For this reason, they have to discover possible points of consensus, with considering the overview of each other's background domain. And, each domain is too complex to be understand quickly in the beginning of communication. They can not even ask suitable questions about each other's experiences.

Recently, scenario communication came to be supported by tools and theories on chance discovery. The communication is positioned in the process of chance discovery as in Fig. 2, which illustrates the process of chance discovery, called the Double Helix (DH) model [19, 21] . This process starts from a state of user's mind concerned with a new chance, and this *concern* is reflected to collecting *external data*, i.e., data from the object environment, to be visualized by a data-mining tool such as KeyGraph and IDM introduced in the next section, specifically designed for chance discovery. By exploring on this map, i.e., the visual result of data-mining, basic scenarios and their values rise in each user's mind. Then users join a workshop for chance discovery sharing the map. In this workshop, participants begin to understand the relations of *islands* (familiar contexts for participants) and *bridges* (unfamiliar relations between islands) in the map.

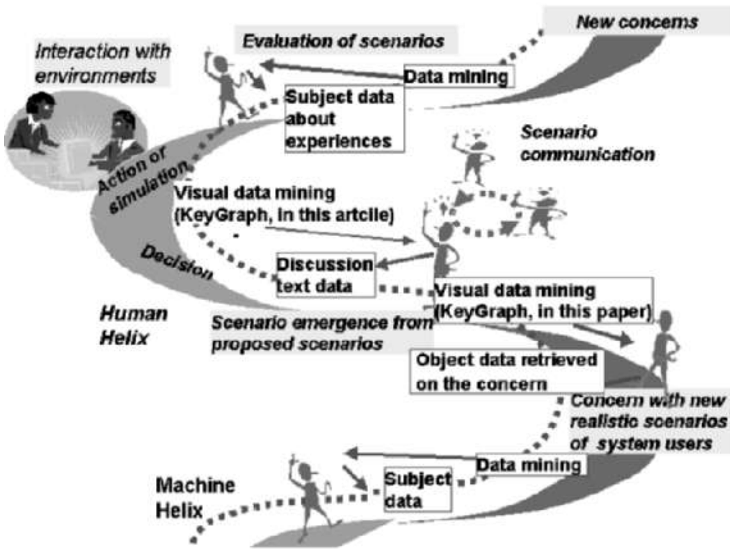

Fig. 2. The double helix process of chance discovery [19].

In the next step, a visual data mining has been applied to the *internal data*, i.e., the data recording the thoughts and messages of participants. Looking at this new map of messages during the communication, the participants notice their own awareness of bridges between basic scenarios, and the islands get connected to have novel scenarios emerge. Here participants may discover chances, because each visualized island corresponds to a basic scenario familiar to some participants and a bridge means a cross of those basic scenarios. That is, connecting the islands via bridges generates a scenario, not confined to an existing island and not too unfamiliar to understand. Based on the scenario selected from those generated here, participant(s) make or simulate actions, and obtain concerns with newer chances - the spiral process progresses to the initial step of the next cycle. As a matter of fact, in the number of successful cases chance discovery were realized by following the steps of double helix [1] (See Chapter by Ohsawa and Usui in Part V).

Even if we get a bunch of visualization tools, the double helix may take the inefficient iteration of cycles, in the worst case forcing to take months for one chance. If the empathy among participants is hard to establish during these cycles, this long process may lead only to a flood of meaningless conflictions. Even worse, the complexity of diagrams visualizing the scenario maps sometimes disturbs communications. Thus, as well as tools for data analysis and visualization, environments for communications and thoughts have been developed for chance discovery.

4 Tools for Chance Discovery and the Environment for Scenario Communications

In this section, let me introduce some of our technical developments. These are formed of tools for visualizing scenario maps and the environment for collaborators' communication about future scenarios.

4.1 Tools for Chance Discovery

We show briefly the outlines of two tools, which have been the most frequently used in real projects of chance discovery in companies. The details of computation schema are presented in the following chapters, and some chapters further improves these methods for respective purposes.

KeyGraph [19, 25] A map showing the relations of events/states in the target environment is visualized. For example, a map of the market is shown on the metaphor of islands (established clusters of consumers) and bridges (unnoticed relations between consumers in islands), if it is applied to consumption data [17]. When it is applied to the internal data, i.e., messages in communication, islands show basic opinions and bridges show new ideas connecting basic opinions. In a textile company, KeyGraphs having real pieces of textile products put on its surface has been introduced. This realized an exceptional growth in their sales performance [30](Chapter 19 of this book), and made a trigger to start their process of chance discovery. In DISCUS, the collaboration of Illinois University and NCSA, KeyGraph is made from communication content, and is always visualized during the on-line communication. This enabled to enhance innovative scenario-communications in the domain of marketing. The recent versions of KeyGraph [7] (Chapter 20 of this book) have the functions to accept user's annotations on the graphical results.

A visualized map showing the relations of events/states in the target environment is useful for participants of a scenario communication in exploring event-relations where scenarios can be drawn, as in Fig. 1, based on personal experiences in their minds. We call this map a scenario map. KeyGraph is a tool for visualizing a scenario map. If the environment represents the world of daily life of people, an event (e.g., "Q3-1") may represent an answer (e.g., choosing '1' from '1' and '0') to a question (e.g., "Q3") in a questionnaire about daily lifestyle. By visualizing the map where answers appear in a graph as in Fig. 3, one can see the overview of the behaviors of survey subjects. In this case, a period ('.') is put at each end of one subject's answer-set. E.g, let $D1$ be: $D1 =$ "$Mr.\ A$: Q1-1 Q2-1 Q3-1.

$$\begin{aligned}
&Mrs.B : \text{Q1-1 Q2-1 Q3-1 Q4-1.}\\
&Mr.C : \text{Q4-1 Q5-1 Q7-1 Q8-1.}\\
&Mrs.D : \text{Q5-1 Q2-1 Q3-1 Q5-1 Q7-1 Q8-1.}\\
&Ms.E : \text{Q1-1 Q2-1 Q7-1 Q8-1 Q9-1.}\\
&Mr.F : \text{Q5-1 Q7-1 Q8-1 Q9-1.}
\end{aligned} \tag{2}$$

KeyGraph, of the following steps, is applied to D1 ([20]for details).

KeyGraph-Step 1: Events appearing many times in the data (e.g., "Q1-1" in Eq. (2)) are depicted with black nodes, and each pair of such frequent events occurring often in the same set (e.g., in the same sequence ending with a period) is linked via solid lines. For example, Q1-1, Q2-1, and Q3-1 from Eq. (2) are all connected with a solid line. Each connected graph obtained here forms one island, implying a basic context underlying the belonging events. A clustering method as in [13] can be applied here.

KeyGraph-Step 2: Events which may not be so frequent as the black nodes in islands but co-occurring with multiple islands, e.g., "Q4-1" in Eq. (2), are obtained as hubs. A path of links connecting islands via hubs is called a bridge. If a hub is rarer than black nodes, it is colored in a different color (e.g. red) than black. We can regard such a new hub as a candidate of chance, i.e., an event significant for context-jumping decisions.

In the example of Fig. 3, the result of KeyGraph, the island {Q1-1, Q2-1, Q3-1} means the basic context of established popularity e.g. preference to use mobile phones, and the island of {Q5-1, Q7-1, Q8-1} shows another basic context such as the preference to listen to music by CD players. Then, the bridge "Q4-1" representing an answer "Yes, I use a mobile phone for listening to new music" may mean the instrument for listening to music can change from CD players to mobile phones. If there are clues to determine temporal or causal directions between events, the user may put arrows to the links in the corresponding directions. Then, the scenario map can be the basis for drawing scenarios.

In Fig. 4, the result of KeyGraph for D2 in Eq. (3) below, the island of {customers} means the basic context about customers, and the island of {steel, concrete, company} shows the basic business context in the mind of people chatting. The bridge"restructuring" shows the company may introduce restructuring, where employees may be fired, for acquiring the good feeling of customers. "Restructuring" might be rare in the communication of the company staffs, but this expresses their potential concern about restructuring in the near future.

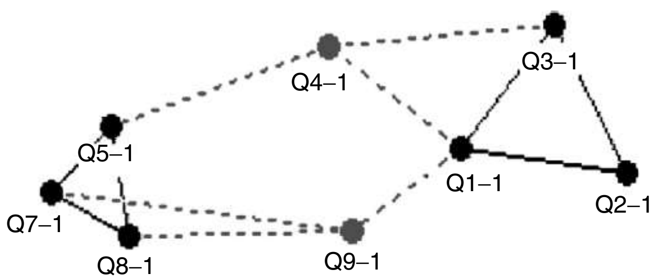

Fig. 3. An example of *KeyGraph on Polaris*: Islands are obtained from $D1$ in Eq. (2), including event-set {Q1-1, Q2-1, Q3-1} and {Q5-1, Q7-1, Q8-1} respectively. The nodes in and outside of islands show frequent and rare events respectively, and Q4-1 and Q9-1 here show rare events in bridges between the two islands.

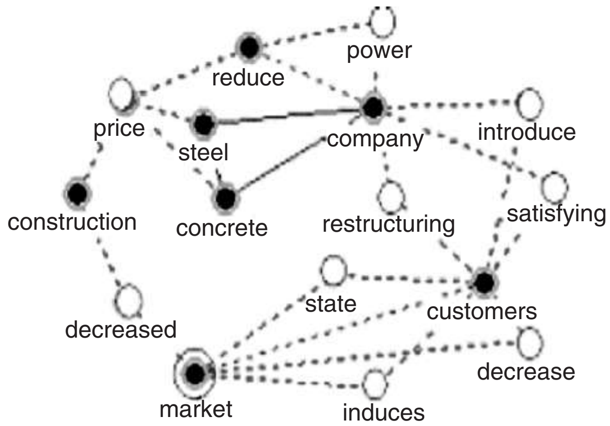

Fig. 4. An example of *KeyGraph*: Islands are obtained from $D2$ in Eq. (3), each including event-set {market}, {steel, concrete, company}, {customers} etc. The double-circled nodes and white nodes show frequent and rare words respectively, forming hubs of bridges.

$D2 =$ *"Mr. X: In the market of general construction, the customers decreased.*
Mr. Y: Yes . . . Our company, building from concrete and steel, is in this bad trend.
Mrs. Z: This state of the market induces a further decrease of customers.
Our company may have to introduce restructuring for satisfying customers.
Mr. W: Then the company can reduce the price of concrete, steel, and construction.
Ms. V: But that may reduce us the power of this company." (3)

As in [22], we can also focus on the most interesting part of the dataset by using Boolean search. For example, if we enter "concrete & (market | customer)," the sentences including "concrete" and either or both of "market" or "customer" are chosen from Eq. (3). Then we can read messages about the market or customers of a concrete-production company. As user likes, the extracted sentences can be visualized by KeyGraph, and the user can see the structure of conversations relevant to the market of concrete products.

Influence Diffusion Model (IDM) [14] (see Chapter 7), Whereas KeyGraph visualizes a map of events, commercial items, words, and messages, shown as a set of islands and bridges, IDM shows the influence flows among those items. IDM has been applied to the intra-company informal discussion board, and the manager noticed potential leaders of opinions in her section, and potential desires of the section members [15]. The integration of KeyGraph and IDM made successful discoveries of hepatits scenarios [23].

Since *KeyGraph* appeared, some researchers of chance discovery have been presenting the importance of understanding chances on the bridges among islands, and studying how the bridges can be visualized, extracted and recognized to make a decision, in the corresponding real world domain. At the same time, their most important domain was the communication of human because the tipping points in human society emerge from the communications of people from multiple domains.

In Fig. 5, let us show an exemplification of IDM applied to oral conversation by 8 people discussing about the information ethics on the Internet. Each node here depicts one message, and a thin link with arrow points from a message to one responding to it. The response to a message is identified by choosing a message succeeding many words from the original message. In this figure, islands are the fat clusters of messages surrounded by dotted circular frames.

Each frame has a meaning as marked by the bold large letters. The colored nodes mean influential messages extracted by the method shown below. These colored nodes are extracted by the computation of the *influence* of each node to the overall community discussing. This example shows the bridging parts of the structure make the appearance of a new context in the conversation.

The number on each arrow means the rate of words, inherited from the arrow-tail, of all words in the arrow-head message carried from the original message C1 of which the influence is being considered. These numbers are multiplied along paths from C1 to all other messages following the arrows, and the products obtained for all these paths are summed up as the *influence* of C1.

If message X is more influential according to this computation than its child (neighbor in the lower stream), X tends to have many children. If X

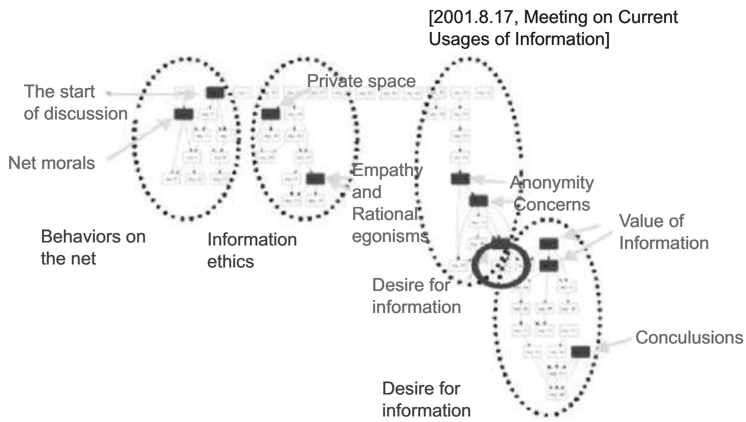

Fig. 5. The islands (dotted circles), bridges (between islands), and the keys (red nodes) in a chain of messages.

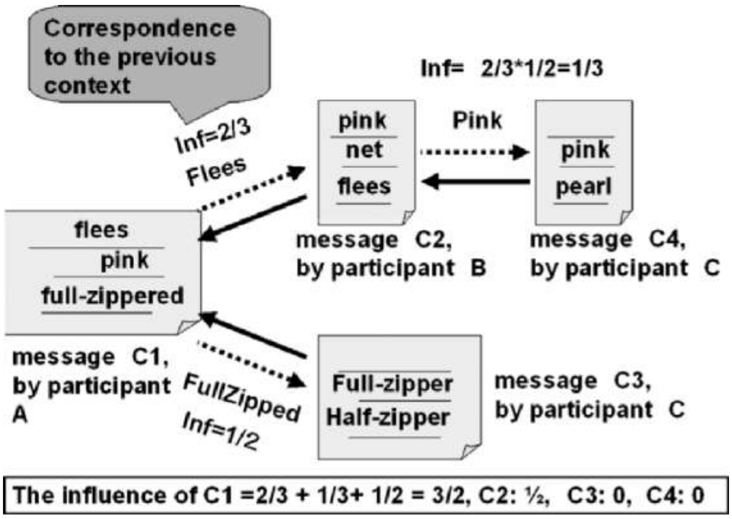

Fig. 6. The computation of influences of messages.

is more influential than its parent, it means the topic of X changed at X and the new topic diffused in the lower stream of X. That is, a message of (locally) largest influences has the strongest impacts on the context-shift in the communication. Such a message is colored as in Fig. 5. By words in such messages, customers can be activated and make expands the market.

For on-line communications in well-designed sites, this method can be used more easily than real conversations because the responding relations among messages can be easily extracted. See Fig. 7. This is the result of IDM for an on-line fan-club of Uniqlo, the biggest brand of casual cloths in Japan. You see the most influential messages are in one path, i.e. the path relevant to pale-olive colored flees. In this manner, the most influential topics tend to appear in a line in a message chain.

In the similar manner as in the chain of messages, we can find the chain of people as in Fig. 8. Here, the word-inheritance between people are numerically dealt with similarly to between messages in Fig. 6, and the people who talked less frequently were sometimes obtained as more influential. As in [3, 4] the results of human chains were validated to be perfectly precise, according to the participant of discussion about architecture.

4.2 Environment for Thoughts and Communications

We can count some previous work on creative communications. In ThinkTank$^{\mathrm{TM}}$ [3] (http://pbl.stanford.edu/Research%20Projects/thinktank.htm), messages in a lot of topics are entered in the corresponding thread, and participants can switch between difference threads. For each entry of message, a new thread may be set if user likes to talk in a new context. More

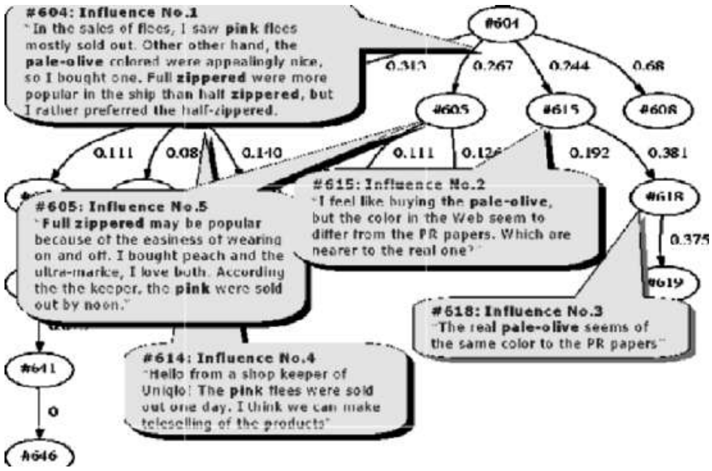

Fig. 7. The chain for an on-line community of fan-club Uniqulo.

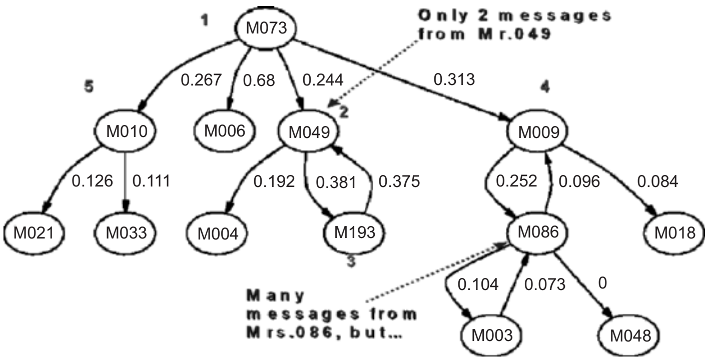

Fig. 8. The human chain from on on-line community.

significantly, data relevant to each message is posted and deposited during the conversations. This way of storing data is apparently useful in reusing the data as external data in Fig. 2, relevant to user's concern, because user's concern is normally expressed in natural words in messages, and such words are linked in ThinkTank$^{\mathrm{TM}}$ to data posted by senders. Frucher et al found topics influential to members' future activities from the text of ThinkTank$^{\mathrm{TM}}$, by visualizing with KeyGraph [5].

Fruchter also invented RECALL [2], an integrated tool for aiding design, where various kinds of internal data (data about thoughts and communications) are thrown but are too deep to be saved as explicit knowledge in the mind of designer hem/herself. RECALL is a powerful tool for showing significant pieces of information about some past message he/she feels important but cannot recall explicitly. For example, a group of users keep drawing images about their own ideas, speaking frankly about what they felt and thought, during communication about their business scenarios. These words about intuitive thoughts are hard to write down in a notebook, so they sometimes find it difficult to restore what they discussed, after the session. RECALL allows them to click on a component of the image they drew on the way of communication, and plays the sound RECALL recorded when the users drew the component. They will say "Yes, this is what we thought at that time!" In this book, Fruchter extends her works on social intelligence design (SID), i.e., design of the environment for creative communication, integrating her SID technologies and the concepts on chance discovery.

We also consider the importance of a member's role in a collaborative community. A leader must choose an action that increases benefit and reduces risk. When the leader cannot make such a decision, the group's action will be determined through community member' discussion. However, this decision cannot be made in blind discussions, so that a systematic discussion is necessary to choose effective action in a limited time. Here, the interleaving of divergence and convergence in the discussion according to members' common knowledge and background leads to that effective conclusions. In Part III, Sunayama proposes a bulletin board system framework in which the scenario creation, a series of actions to be undertaken, is established through the discussion and exchange of opinions.

Whereas Llora et al presented the method for reflecting the users' thought onto the output of KeyGraph applied to the text data of communication [12], Iwase and Takama presents a bulletin board system where users can annotate on the map presented by KeyGraph for given external data. They started this work since 2004. In Chapter 17, they show some experiments showing the running of their on-line system. Here, the mapping to the graph generated by KeyGraph and the scenario drawn up by a user is proposed. The mapping is used for extracting the data referred to in the scenario and for annotating those in the original data file. The annotated data files are expected to be used for further data analysis as well as for supporting group discussion.

5 Further Progress with Basic Research

Recently, studies came to be dedicated to experts working in real world domains where discoveries of hidden links are desired. We can say Chance Discovery is one of the leading research domains which began to run from 2000 in this direction.

A relevant research area to Chance Discovery is Evidence Extraction and Link Discovery (EELD), where important links of people with other people and with their own actions are discovered from heterogeneous sources of data [16, 29, 27]. The difference between Chance Discovery and EELD, for the time being, is in the position of human factors in the research approaches. In Chance Discovery, the visualization techniques such as KeyGraph have been used for clarifying the effect of chances, by enforcing the user's thoughts on scenarios in the real environment. On the other hand, the EELD program mainly contributed to identifying the most significant links among items more automatically and precisely than human. I expect these two will meet, because the latest studies in EELD is oriented to coupling symbolic expressions of human knowledge with a machine learning system [28], whereas chance discovery has been integrating the human process of externalizing the tacit experiences and the power of machines for finding a surprising trigger to the activation of the environment. That is, human's interaction with machine intelligence is coming to the centers of these two domains. Some studies in EELD, such as data visualization for decision making [11, 10], serve bridges between human and machine.

However, the complexity of the real world was sometimes even beyond the reach of both Chance Discovery and EELD: A few nerd users of cellular, not frequently sending out comments, are likely to create new fashion causing strong influences on other users. The developer's question is "where is the innovative user?" It is meaningless to ask hundreds of monitors "who gave you the idea to use cellular this way?" because users seldom know the innovative users, but only see other users' accessories of cellular which are the indirect influences of the innovation. As a result, neither comments nor names of innovators can be included in data. Here arose a problem of Data Crystallization.

This may be the meeting point of Chance Discovery and EELD: The detection of unobserved but significant events, as a grand challenge ignited in [24] and presented by Maeno and Ohsawa in Part VI in this book. Data crystallizing means this challenge, and to extend Chance Discovery to the discovery of significant events in more uncertain environment. And, the sphere of real world applications linked from this basic research is expected to include intelligence analysis, development of new products, aiding corporate activities by detecting interest of employees, etc.

For example, let us consider the intelligence analysis, where expert investigators of criminal-group behaviors are exploring missing links among members. The head boss (see the dark guy at the top of Fig. 9) of the criminal organization may phone a few times to sub-leaders managing local sections (Mr. A and Mr. B in Fig. 9). For responding to these top-level commands, each local section holds its internal communication, via different media from that the boss used for contacting sub-leaders. Then, sub-leaders may meet to achieve consensus before responding to the boss. Meanwhile, the boss does not appear in the meetings. In this way, some who is never observed in meetings or mailing lists may be the real boss.

In the study of Data Crystallization, our research team is revealing events potentially important but never observed. For example, some leaders of an online community were deleted from the data of conversation, and our method was applied to the "cleaned" data. As a result, the participants who were most tightly linked to the leaders came to be visualized, and finally the leaders

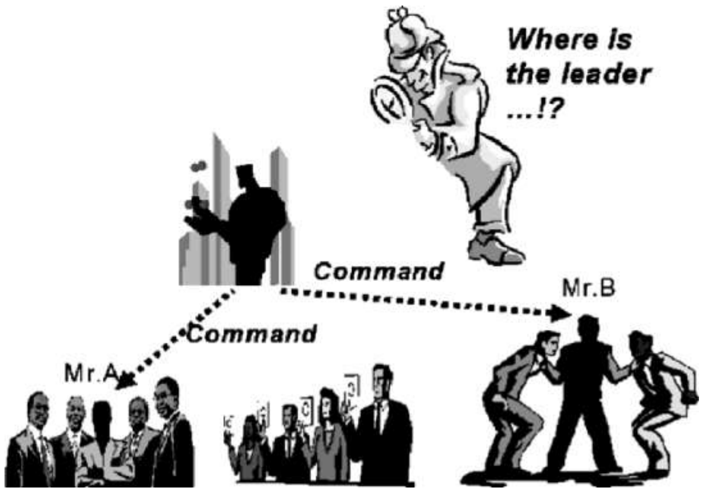

Fig. 9. Intelligence analysis seeking hidden leader.

were identified by investigation of their real human relations. Because such leaders are not included in the data, existing mining methods hardly help in identifying them. Data crystallization is the challenge to this hard problem from an extension of what we have been calling Chance Discovery since 2000.

6 Conclusion of this Chapter

KeyGraph and IDM are not the only techniques for chance discovery. Computation approaches on the Bayesian, the Fuzzy methods that have been developed and employed for dealing with uncertainty in the future are other promising tools as Chai et al and Hubey presents in Chapters in Part II. These may also be mixed with the methods of Data Crystallization.

We should also note that the process of chance discovery is not completed by the Double Helix process. Before everything, the participants of scenario communication should have a prepared mind. In business, one should be prepared for dealing with customers. In all daily life, human has to deal with his/her own and others' value criteria and morals. The Chapters on scenario communication applicable to business by Yada, and on the cognitive aspect introduced by Magnani are two bases for developing a new generation process of chance discovery.

Finally, as pointed out in this Chapter, we should keep in mind that the word "chance" includes the meanings of both opportunity and risk. Whereas the Chapters in Part V show chance discovery methods for finding opportunities for business success, we includes major works on risk discoveries in Part VI. Focusing on the medical topics [Chapter 22 through 24], reader will find how human's attention and concern with risks are to be integrated with the real information in the environment. Chance Discovery, after all, is a research domain about human interaction with the complex and dynamic environment via the exchange of revised information.

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The Structure of Scenario Communication and Chance Discovery

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Summary. The objective of this study is to focus on the structure of the inter-communication process that occurs in human scenario communication leading to opportunities for the creation of new scenarios. A "scenario" is defined as story that provides a broadly stated description of future events. We examine the case of a joint research project with a company that established a research method for measuring awareness of TV commercials based on using mobile telephones as the process of he emergence of a new scenario from existing and new technology. This paper does not deal in detail with the subject of discovery of a chance. However, we attempt to clarify the creation process of new scenarios after a chance discovery takes place and their incorporation into actual business activities. We also examine various types of scenario communication and drivers for promoting scenario communication. Finally, we discuss the future prospect and direction of the chance discovery research from the viewpoint of scenario communication.

1 Introduction

For the past several years, some applications have been developed for use in the process of discovery of a chance such as KeyGraph [4] and IDM (Influence Diffusion Model) [3]. Several cases exist where these tools have been applied in the business world and have resulted in significant successes [6] [8]. These cases of actual chance discovery have many important implications and it is very important to study these implications from many different points of view. In this paper, we will focus on a case concerning the development of new market research methods that involved new scenario emergence as a chance discovery process.

Chance discovery is a process to determine an important event for the purpose of decision making. To encourage the chance discovery process, participants exchange scenarios with each other and, by means of this process, create a new scenario. This creation of new scenarios is called "scenario emergence." The structure of this process can be described as indicated in Figure 1.

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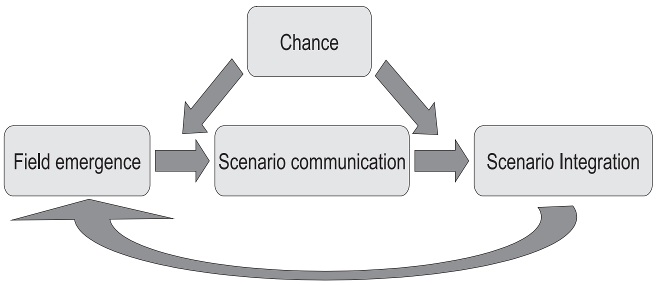


Fig. 1. The structure of Scenario Emergence.

In the emergence environment, under the influence of key events, participants exchange scenarios, a process called "scenario communication." From this process of scenario communication, new scenarios are born and integrated with existing scenarios and during discussion sessions, in an intercommunication environment, or space, new scenario communication is generated. The chance factor serves as a trigger for the new scenario emergence. This process is called "double helix model of Chance Discovery" communication process [5].

Ohsawa [5] has suggested a double helix model for a joint and combined process of human and computer chance discovery with the factor of human selective interest at its center. In the case of process related to chance discovery, the delineating interest of human beings that are involved in the process plays a central role. "Object data" obtained from the usual measurements of the environment and "Subject data" obtained from the thought processes based on the discoverer's guiding interest involve analysis, evaluation and repetitive behavior and lead to the realization of new chances.

Figure 2 shows the double helix model conceived by Ohsawa [5]. The upper part of the Figure 2 is based on the Fayyad general model of the data mining process. At the outset, the process is based on the analysis objective that is used to select the target data. This data is subjected to preliminary processing to obtain the correctly shaped data sets. Lastly, a suitable data mining algorithm is used to derive patterns with special characteristics. In the case of this preliminary data mining process, until useful knowledge is discovered, these processing cycles are repeated. These processes are carried out for most part by using computers. The real chance discovery processes are driven completely by the paths of human interest and the processes of evaluation, analysis and interpretation of the environmental data that arouses this type of interest are shown in the lower part of the Figure 2.

The various types of data obtained from the environment arouse human interest. The conditions (environment) are understood and some type of action is taken or simulations are carried out. The chances inherent in the situation are evaluated. This causes further new types of selective interest to emerge

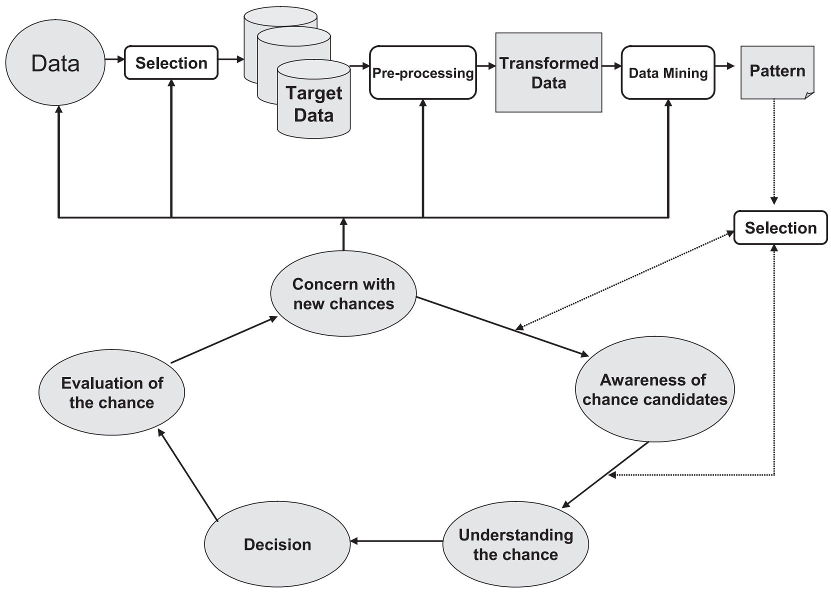


Fig. 2. “Double-helix” Model in Chance Discovery.

and based on these various types of interest, new data is generated and the data mining process is repeated. The double helix model indicates that the human and computer discovery process functions in an integrated way. Thus, an increase in the depth of human interest is generated and this process is revealed. Within this process to reach chance discoveries there is a scenario leading to discovery.

Case studies of this process of scenario emergence, for the purpose of understanding the phenomena related to new scenario emergence and examination of the theoretical background of new scenario emergence, have not been carried out in sufficient numbers as yet. Thus, in this paper, we focus on the process involving inter-exchange of scenarios among multiple participants and the emergence of new scenarios through this scenario communication. In addition, we present a new conceptual framework for understanding this process. The objective of this study is to perceive various techniques and methods as single scenarios and to string them together to clarify the types of communication that take place when new scenarios are created. In this paper, a case involving the development of the use of mobile telephones for establishing market research methods for measuring respondent awareness is used as an example of the process. We do not formally discuss the factor of chance discovery as such in this paper. Rather we discuss the integration of such chance discovery as real scenarios, from the perspective of business management at the point after which a chance has been discovered.

2 Case Study: The Use of Mobile Telephones for the Development of TV Commercial Awareness Market Research Methods

In this paper, we introduce a case involving the development of the use of mobile telephones for researching advertising effectiveness and discuss the process by means of which multiple scenarios were generated. At first, this project was a joint undertaking involving a Company A with a high level of strength in the processing and marketing of vegetable-based products and another Company B with strong abilities in the development of Internet systems plus our organization that has in-depth experience in the development of data mining systems for analyzing consumer behavior data. And new findings caused Company A to emerge new motivation for in-depth consumer behavior analysis depending on their interests. Then the new project of these methods in other area has been carried out based on these successful results. (Figure 3 uses this case to illustrate the development process of research methods).

2.1 Starting the Project of Chance Discovery

In Japan, when marketing managers carry out an audience rating research of TV programs and commercials, ordinarily, they use consumer panel data provided by a research company. We were made aware of a need on the part of marketing management personnel for additional sources of consumer viewership data, a need that became the source of a chance discovery for our organization, through another joint project with Company A.

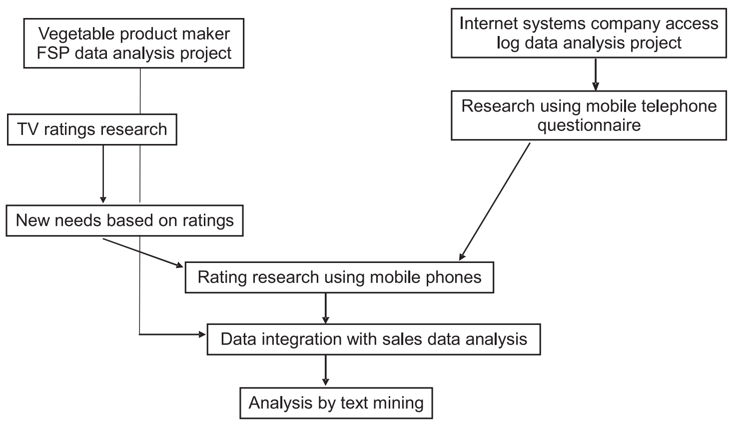


Fig. 3. Scenario Emergence Related to Rating Research Using Mobile Telephone Questionnaire.

We carried out a joint project with the Company B mentioned above that builds and manages many Internet sites. This project was aimed at analyzing access log data on their sites. During this project, we realized that their mobile telephone site had a wide membership throughout Japan that included many different age groups and we learned that it was possible to carry out large-scale market research projects based on questionnaires. Ownership of mobile phones is high in Japan and very large numbers of persons can use mobile telephones that have functions for e-mail and accessing the Internet. Also, this company has extensive consumer data concerning its site members that can be broken down by age, sex and residence area, etc.

In the course of our communication, we discovered that the needs related to viewership and this type of related technology offered a chance to create a new type of market research related to TV commercials. We concluded that with the help of the technology of the Internet systems company and its network resources, it would be possible to collect accurate data concerning specific consumer subgroup reactions to a given commercial in a short period of time. Thus, we decided to use a simple mobile telephone-use questionnaire to test out awareness research concerning TV commercials.

2.2 Emergence of New Research Needs and Generation of Hypotheses

With the help of Company B, sample data were collected by means of a simple mobile telephone questionnaire and used for discussions with the marketing personnel of Company A. At the time of these discussions, since it was possible to collect the data in a very short period of time when a telephone questionnaire was used, the idea of using characteristics to collect time-series data concerning TV commercial changes of awareness levels over time was born. At that time, Company B had not been carrying out research at specific points in time and the idea of researching changes of member awareness over time did not exist.

In addition, the marketing manager of Company A also came forward with the idea of researching the relationships between TV commercial awareness and retail sales. This idea was partially based on his knowledge of our advanced data analysis skills that were known to him because of our analysis of his company's FSP (Frequent Shoppers Program) data as part of a joint project [1] [2] [9] [10], that is systems and tools to implement the effective CRM (Customer Relationship Management) strategy to identify the loyal customer group to the store and to analyze the purchase history data to understand their purchase behaviors. The marketing staff was well aware from their professional experience that there was a time lag between the time that the commercial began airing and the time that the effect of the commercial appeared in sales results. However, they did not know the implications related to specific points in time and the level of effect on sales.

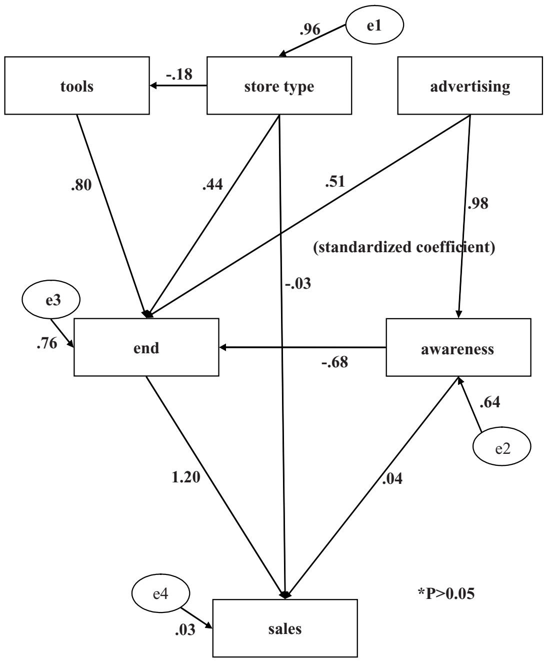
He thought that if it were possibly a new method to research retail outlet sales data and retail in-store sales promotion material data could be made available through our organization's skills, then it would be possible discover new relationships between TV commercial frequency, awareness and retail sales. Furthermore, we consider FSP data, which concern the relationships between past individual consumer behavior and the effectiveness of a given TV commercial. If we used a data mining technology that we had developed to analyze these FSP data, we would be able to gather very detailed data to gain hints concerning new marketing strategies.

2.3 Research Methods and Procedures and Their Theoretical Implications

From this point onward, our organization played a central role in designing the actual research procedures. During the period when TV commercials were being aired, questionnaires were administered at three different points in time. A version for each given TV commercial for use with mobile telephones was produced. Questionnaire items were determined. After these tasks were completed, verification of the research procedures and methods was carried out. It appears likely that the research methods that we are attempting to develop will make contributions to the field of marketing research [7] in the following areas:

- The use of mobile telephones for awareness level research.
- Since the design of the questionnaire content is free and not subject to any particular restrictions, the relationships between recall of the name of the maker, the brand, the given TV commercial, etc. and sales can be clarified.
- It will be possible to include detailed variables related to in-store merchandising methods and materials.
- By using data mining technique, it will be possible to determine the relationships between consumer purchase behavior and the effectiveness of given commercials on an individual consumer basis.

Based on these research methods, it becomes possible to integrate various types of data that were processed separately up to this time. In turn, this has made it possible to understand more completely the inter-related aspects of the various cause and effect factors that are found in consumer purchasing behavior. Figure 4 shows a clarification of the relationships between several factors related to sales such as the amount of TV commercials shown, the level of consumer brand recognition and the positioning of the point of sales within the given outlet. The results obtained from SEM iStructural Equation Modelsj are also shown. These models tended to indicate that the amount of television commercials shown and the rate of consumer brand recognition did not have a significant direct effect on sales. However, the gondola-end point of



	RMR	GFI	AGFI	PGFI	AIC	BCC	BIC	CAIC
Model	10.771	0.962	0.842	0.229	37.325	43.379	66.232	82.232

Fig. 4. The Results of SEM with Various Factors Related to TV Commercial of Company A.

sales (In-store point of sale location), a major factor in the in-store promotion, had a clear indirect effect on sales.

2.4 Detailed Analysis Based on Analyst interest factors

When the Company A marketing staff came to understand the results indicated above, in order to carry out effective in-store promotions, they wanted to investigate consumer perceptions of the products in more detail. At this point, a survey using mobile phones to obtain open answers in questionnaire format, together with group discussion-generated textual data, was used to investigate consumer perceptions of the target products. Figure 5 is based on textual data obtained by means of an open-ended questionnaire concerning the packages used for Company A products. The image data to product package of Company A was analyzed using a KeyGraph and the results are shown in Figure 5.

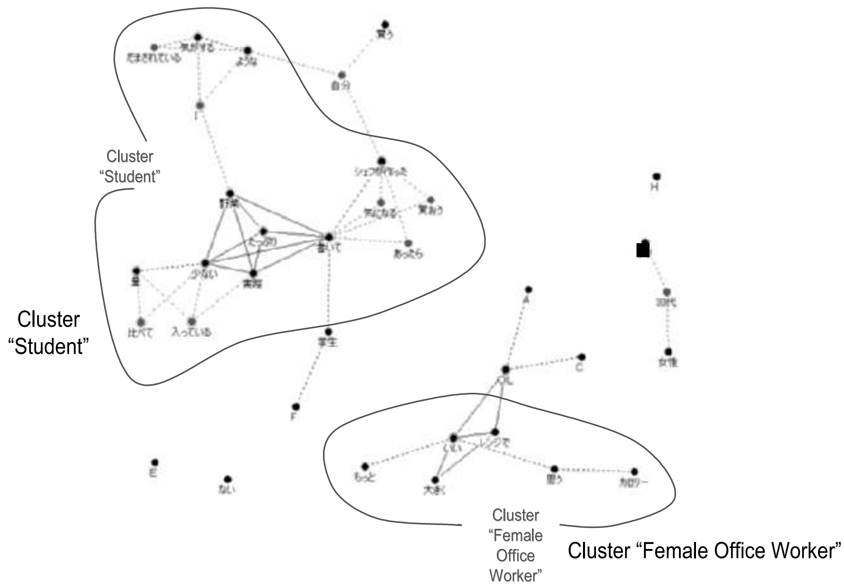


Fig. 5. Results of Analysis of the Open-ended Data Concerning the Packages.

These results made it possible to discern at least two significant sub-groups of consumers. The first sub-group consisted of students. This group tended to focus on the amount in the package that was indicated and on the name of the chef. The second group consisted female office workers. These consumers are able to use electric ranges to prepare food and also have a high level of interest in the calorie content of what they eat. It is clear that, depending on the type of consumers, perceptions of the packaged differed widely.

Based on this result, we focused on the supermarket customers and tried to identify sub-groups of consumers. Using Purchasing Member Card data, it was possible to separate purchasers, using a clustering method (k-means), three different major types of customers as are shown in Figure 6. Cluster 1 consisted of customers that often purchase boxed meals and salads. Cluster 2 consumers virtually never purchased boxed meals. Their purchases ended to include many types of fresh ready meals sold to be eaten with rice. Cluster 3 bought only salads. In order to help Company A to be able to develop separate sales promotions for these three types of customers, we are carrying out a series of experiments at the present time.

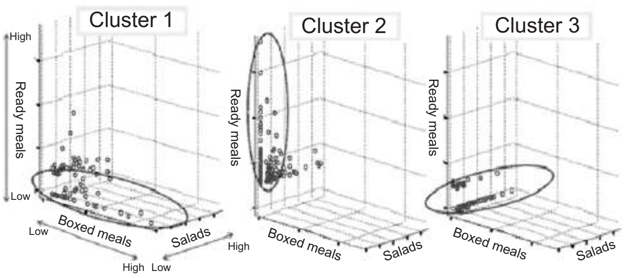


Fig. 6. Three Major Types of Supermarket Customers.

2.5 Projects to Generate Chance Discovery in Other Categories

Most of the results of this analysis project have been announced at various workshops and we hope to cause other companies gain a new level of interest regarding different categories of products. For example for the case that was discussed above, a Japanese manufacturer of confectionery has expressed interest in the results and we have adapted this research framework for the purpose of studying confectionery. In the case of this project, we discovered that the effectiveness of confectionery commercials in terms of sales reaches a peak in the second week of a TV campaign. A product image study was also carried out concerning TV advertising for confectionery products. The open answer data from this project was analyzed using KeyGraph and the results indicated that reactions to these products as presented in TV advertising were divided into a group that sensed a type of "emotional feeling recall of previous similar products" and another major group of consumers that perceived the TV advertising as "surprising/strange".

3 Scenario Emergence

The process of chance discovery can be defined as a process of evaluating and interpreting multiple scenarios of the various participants and emerging new scenario coming out of significant events for the purpose of making important decisions. In this paper, the story of the usage of a specific technology, in other words, the motivation, the objective and the methods and results obtained, will be used as elements of a scenario. In this section, while referring to the case described in the previous section, we will present a framework or explanatory structure for the purpose of gaining a better understanding of the concept of scenario emergence.

3.1 Definition of "Scenario"

It is possible to define a "scenario" as story that provides a broadly stated description of future events. In the case of this paper, we deal with the process

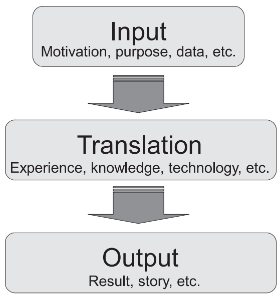


Fig. 7. The Major Components of Scenario.

of the emergence of a new scenario from existing and new technology. It is possible, in simple terms, to characterize a scenario as consisting of three major components, as shown in Figure 7.

The first component of a scenario is "input." In order to imagine a story of the future, it is important for participants in the process of creating a scenario to determine the underlying motivations of creating the scenario, what the objectives are and what the materials that are to be used (data) consist of. The values held by the participants and their motivations will exert a very strong influence on the process. The term "translation" refers to the process of imagining various scenarios of the future based on the input. At this stage, the past experience and the knowledge of the participants, and technology will probably lead to creation of scenarios. There are cases where specific technologies and common experience will aid the translation process. The term "output" refers to the results of the "translation" stage referred to above. These results often take the form of stories, business models, etc. Even in cases where the inputs are the same, if the translation process differs, differing output will result. In the same way, even if the same translation process is used, if the input differs, the output will differ.

As a simple example of this, let's look at the case of the scenario emergence that company B has regarding the questionnaire research methods using mobile telephones. Company B has established a method for using questionnaire research administered by the use of mobile telephones to obtain consumer data that is of interest to its clients. Figure 8 shows a view of a mobile telephone questionnaire that was used to obtain data related to the level of popularity about a certain musician carried out for an advertising agency.

A research method can be perceived as a scenario. For input, as one of the major components of the scenario flow, there is "Need to know level of awareness of musician" (Motivation). Company B's "research using mobile telephone questionnaire" is the translation phase. And, the output is "musician popularity ratings by age groups." In the same way, the development of new technology and methods can be perceived as emergence of new scenario to turn various scenarios (technology and methods) into new one.

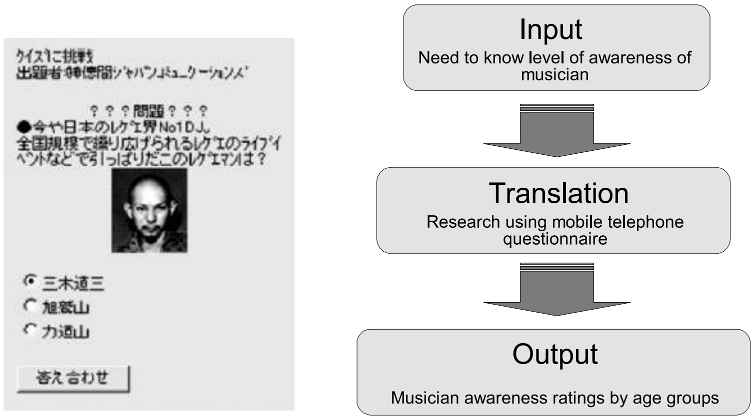


Fig. 8. Image of Research Page Showing Mobile Telephone Questionnaire and the Scenario Flow.

Table 1. Types of Scenario Communication.

		Method of translation	
		Existing	New
Input	Existing	Exhange	Substitution
	New	Application	Analogy

3.2 Types of Scenario Communication

In the existing study of chance discovery, it has become clear that the communication of the scenarios held by the various participants can result in the creation of new scenarios related to chance discovery process. In this way, "scenario communication" can be defined as the communication-based exchange of various scenarios held by multiple participants gathered at a certain field that leads to the emergence of new scenarios [11].

Based upon two dimensions: input and translation modes, we can identify the various types of scenario communication by using a matrix (Table 1). There are four types of scenario communication. For existing objectives, existing technology can be used to obtain the results (output). This case is termed "exchange." For a new motivation and objective, a case of "application" is defined as the use of existing technology. When new technology is used for an existing objective, this is termed "substitution." And, when a new technology is used for a new objective, this is termed "analogy."

The categories of scenario communication change with the viewpoint of the party with the basic scenario (See Figure 9). Consider a case, where through scenario communication, it is realized that a mobile telephone questionnaire research method can be used to measure TV commercial awareness levels. The

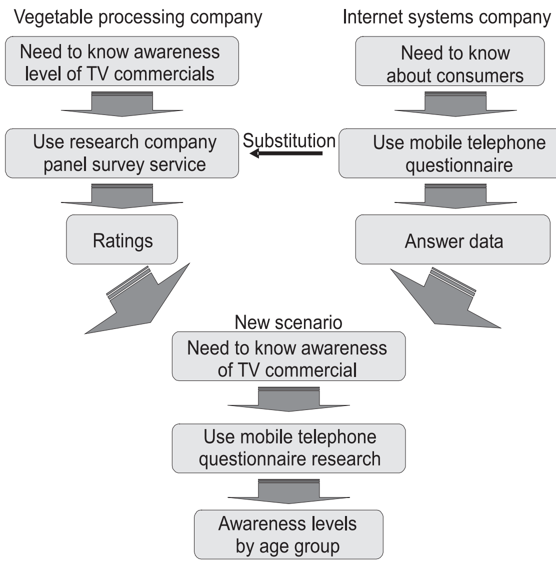


Fig. 9. Scenario Emergence from the Viewpoint of Company A.

marketing manager of Company A, who is motivated to carry out awareness research, adopted the use of a research method based on mobile telephone questionnaires; this is a "substitution" type of scenario emergence. However, considering the viewpoint of Company B, there is an existing questionnaire research technology, which is then used for TV commercial awareness research, a new objective that is an "application" and this can be perceived as a process that creates new value.

In the case of interchange of scenarios based on these types of communication, the participants adopt each other's scenarios, either completely or partially, and a new scenario emerges that, it can be perceived, is then integrated with other related, existing scenarios and through time this process is repeated. Within this cycle, the selection of the form of translation changes constantly and, new business models and scenarios are created as the end product of this process. The future directions of our work are to develop useful applications to promote these transformations that stimulate and support the chance discovery.

4 The Driving Force of Scenario Communication

Scenario communication cannot be carried out effectively in just any type of field and with any type of participants. It is possible to list the conditions that are necessary to carry out effective scenario communication. First of all, the field in question should be one that has been an area of previous joints efforts of all or a part of the participants who have the "experience" of participating in joint projects. The participants will have the common and tacit knowledge with mutual experience and the understanding of each other's values that is necessary for communication and trust in each other. By understanding the values held by the other participants, it is then possible to understand the scenarios of the other parties with accuracy. Likewise, it becomes possible to communicate one's own scenarios more easily. The term "trust" as it is used here refers to the belief in the possibility that the other party will carry out the plan. This trust is a product of past successes and based on this, it is possible to maintain the motivation to carry out new scenarios.

Concerning the cases discussed above, our organization and Company A have the experience of carrying out a joint project in the past involving the analysis of FSP data and this experience had the effect of stimulating scenario communication. They knew about our skills in analyzing consumer behavior data and believed that we could accomplish the scenario in this case and therefore, they cooperated with us. We also know that they used the results of the previous project with regard to their in-store merchandising and that this application was successful. Therefore, when the scenario of using the TV commercial awareness data in connection with their sales data emerged, we found it easy to imagine that the actual use of the resulting data would lead to the generation of new ideas, such as ideas related to effective in-store merchandising.

5 The Future Direction of Chance Discovery from the viewpoint of Scenario Communication

As a method of promoting the discovery of chances (chances for improving operations) as an important aspect of decision-making, the process requires that various suitable participants exchange scenarios with each other to create, by this procedure, the most desirable scenarios for action. Here, from the standpoint of this type of scenario communication, the important topics of the future of chance discovery will be clarified. Figure 10 indicates the critical related factors of "creation of place", "transfer of knowledge" and organization process" as they relate to scenario communication.

5.1 Field Emergence

The members of the organization all have their own scenario input, that is to say, motivations and goals. Based on communication between persons both inside and outside of the organization, there are occasions when changes will take place. One of the most traditional methods of activating this type of

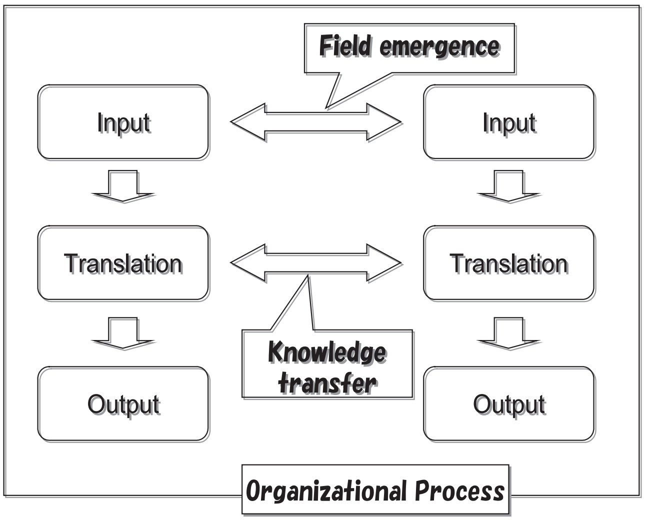


Fig. 10. Study of Scenario Communication and Chance Discovery.

communication is "emergence of field". In the case of the study of chance discovery, this does not involve only such traditional methods group discussions, and meetings. To carry out "creation of place", the development of interfaces for the creation of place, the methods of communication using virtual space, and the various methods of analyzing this data are currently being widely studied and used to analyze data as part of the study of chance discovery. In the future, it is thought that new findings from areas of psychology and group dynamics, etc. will become sources of new approaches to the development of chance discovery theory, method and application development will have a greater role in the development of chance discovery.

5.2 Knowledge Transfer

The methods, technology and knowledge that have been developed must be effectively transferred to participants both inside and outside the company. Thus, even if a given member may not have in-depth knowledge of given methods and technology, there is a need to develop effective methods to transfer knowledge so that necessary understanding can be achieved. For this purpose, the concepts that comprise the basic expression of the knowledge and the definitions of their relationships and the related ontology and the related Semantic Web and the studies of these factors must be effectively integrated. Within the community of parties involved in the research of chance discovery, there has been a sharing of efforts in these areas and it is thought that in the future, the development of a common platform will occur and that this will promote knowledge transfer to persons working in this field.

5.3 Organizational Process

This type of scenario communication will not by itself automatically create value. Within the organization, by converting this knowledge into actual business-related actions, such value will be created. Therefore, there is a need to create new scenarios and to put them into action and organizational process plays a critical roll in this endeavor. As part of the study of organizational process, there is a need to clarify the roles played by such factors as the special characteristics of the scenario communication participants, the structure of the organization, the organization history, its relationships with other organizations, and other related factors in the realization of new scenarios. To express in another way, it can be said that is what chance discovery is all about and this is what must be clarified.

The research of chance has the special feature of involving many different fields of study and research. However, for topics concerned with business, there are several requiring urgent further study and development. They include "emergence of field", "knowledge transfer" and "organizational process", as specified above. In recent years, in the business world, not only chance discovery, but also the creation of new scenarios and the complete, most effective process of putting them into action is being sought. Thus type of study helps to promote the promote discovery of opportunities that are practical in substance and are thought to be providing new chances for opening new horizons in this important area of study.

6 Conclusion

This paper examined the role of scenario communication in the process of emerging scenarios by describing a case study of using mobile telephones for carrying out TV commercial awareness research. The paper clarified the key components of scenarios and indicated the different types of scenario communication. However, there are several important topics that could not be covered in this paper. These include topics related to the integration of those scenarios that are the product of the scenario emergence process and the clarification of the conflicts and the relationships between scenario communication and chance. These will be addressed at another occasion.

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Complexity in the Discovery of Chance: Daily Life Criticality

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Summary. Self organized criticality states that large interactive systems naturally evolve toward a critical state way out of balance in which a minor event can lead to a catastrophe. This chapter introduces the fundamental idea of observed criticality in daily life, seen from the perspective of the discovery of useful and meaningful *chances*. The analogy of considering human trivial conversation, i.e, chat, as a *self organized critical system*, where chances are seen in the context of the completion of a topic and the topic change being initiated, is presented.

1 Introduction

In 1950 a revolutionary dissertation came to light [1] based on the question "Can machines think?" In this dissertation Alan Turing proposed an empirical game in which *language* was the basis for deciding whether the machine could think. The critical issue for Turing was that exercising language as humans do is sufficient to determine intelligence.

More contemporary dissertations, i.e., [2], also propose that the properties of human intelligence can be shown through the properties of language. Hence language could be considered as a representational system. According to [2] instead of the human species growing clever enough to invent language, species blundered into language and, as a direct result of that, became clever. Perhaps we could deduce: the discovery of language *by chance*? Regardless the answer of that question, this chapter will focus on *the chance* involved with language, raised as a direct result of the criticality of language itself.

The criticality of language has been observed since the Harvard University Professor George Kingsley Zipf pointed out simple regularities in systems of human origin [3]. Zipf counted the frequency of the words in the English language and plotted the frequency versus the ranking. The resulting curve in a logarithmic plot was roughly a straight line with slope close to unity.

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This is referred to as Zipf's law. The Zipf's law mathematically expressed is the frequency of occurrence of some event F, as a function of the rank r when the rank is determined by the above frequency of occurrence. The representational formula is a power-law function $F_r \approx r^{-a}$, with the exponent a generally close to unity. It has been shown that systems obeying the Zipf's law posses tendency to self organized critically [4], and language is not the exception to that tendency.

On the other hand, language could be considered as one of the activities of the brain. The brain can be seen as the best example of a complex system. Since complex systems in nature reflects the tendency to self organized criticality, the brain can be considered as self-organizing into a critical state [4, 5]. Moreover, Turing speculated that in order to achieve its stable flexibility and adaptability, the brain must avoid the two extreme levels of over-correlated sub-criticality and explosively dynamic super-criticality, and instead travel the middle path of criticality. If the brain were sub-critical, any input signal could interact with only limited portions of stored information. Conversely, if the brain were supercritical, any input signal would result in explosive branching processes in which new information connects with all previous knowledge [1, 4]. In a critical state, however, the brain could be both stable and variable, and may be optimally suited for information processing. This is concordance with considering criticality as a gray area between order and disorder where rich variable behavior arises. We could argue then that the criticality of language might be a by-product reflecting the criticality of the brain.

In order to express verbal communication, i.e., spoken language, the human specie has developed the code of speech. Speech has been said to be a vehicle of language that defines a set of forms used by a community to carry information. We could argue that speech is the most natural way of interaction - communication - between humans. Through speech humans express their thoughts, and in turn the development of thought is determined by language [6]. Thought can be defined as a process which allows beings to model the world, in order to deal with it effectively according to their goals, plans, ends and desires. Thoughts represent the fullness of life from the personal needs and interests, ideas or intentions, inclination and impulses of the thinker. Each word uttered, therefore, is in inalienable junction with thought and represent the disembodiment of mind of the speaker.

Since the usage of language, as means of speech, is such a distinctive characteristic of intelligence of humanity and sentience, no wonder Turing took it as a measure for evaluating machines as intelligent entities. However, since language is replete with self-organized criticality [3, 4], in order to achieve machines capable to use language as humans do, it is needed to take into consideration the inherent characteristics of criticality that language possesses. In this chapter, the fundamental ideas of criticality in daily life, i.e., from the perspective of language, are going to be introduced. The basis of the analogy of trivial conversation as critically self-organized system is presented in

Sect. 2, along with the extension of this idea to consider criticality in daily life. A discussion of what could be considered *a chance* within criticality is given in Sect. 3. Finally a conclusion, as a way of discussion, is given in Sect. 4.

2 Critical Speech: Daily Life Criticality

Imagine the scenario of someone having a trivial conversation - hereafter *chat* - with a friend. During the chat, there are moments when the interlocutors explicitly agree in their ideas regarding the subject discussed, i.e., playing tennis on the weekend, then the subject ends and a new trend of interest may arise. On the other hand, there are times during the conversation when the interlocutors *implicitly* understand that it is the right moment to talk about something else, and almost imperceptibly with the agreement of the speakers, a new topic begins[1]. This cycle repeats itself until the chat ends. Would not this cycle of shifting topics occur, the interaction could not be considered as a chat but rather as determined topic discussion or as a monologue. Could we regard this unconscious regularity as possessing tendency to critically self-organize? We will deal with the answer to this question in this section.

2.1 The Fundament: Self-organized Criticality

Let us introduce the reader to the basic notions regarding self-organized criticality (SOC). Self-organized criticality is a characteristic of many complex systems in nature, including those of human origin. The concept of criticality came primarily from studies of thermal systems at equilibrium, where scale-invariant - power-law - behavior was observed when the temperature, or other parameter, was near the critical point in second-order phase transitions. Near the critical point, local micro-state changes are no longer limited to short-range effects typical of interaction with closest neighbors; long ranging effects are also observed that could propagate through the whole system. The analogous observation of power-law phenomena in natural systems, like the Gutenberg-Richter law for earthquakes, and in systems of human origin, like Zipf's law of ranked word frequency distribution inspired the adaptation of the concept of criticality to these non-equilibrium dissipative systems [7].

Regarding self-organization, the basic questions about how organization arises have been brought up since ancient times. It has been observed that many natural systems show organization, e.g., galaxies, planets, chemical compounds, cells, organisms and societies. Since complex systems evolve naturally to a critical state without the influence of external forces, the idea of self-organization emerged. Fusing the independent concepts of criticality and

[1] According with the degree of interest, identification, etc., of the speakers with a determined subject, in some cases the shifting of topics is explicitly marked by one of the speaker.

self-organization into a unitary idea of self-organized criticality in order to describe many different complex systems, was the role of Bak [4].

Self-organized criticality has been canonically exemplified through the sandpile model. In this model grains of sand are being added as to create a pile. Describing the model in [4], Bak stated: "In the beginning, the pile is flat but as time goes on the sand slides become bigger and bigger. As the pile becomes steeper small sand slides or avalanches occur. The addition of a single grain of sand can cause a local disturbance, but nothing dramatic happens to the pile... Eventually the slope reaches a certain value and cannot increase any further, because the amount of sand added is balanced on average by the amount of sand leaving the pile by falling off the edges... There will occasionally be avalanches that *span*[2] the whole pile. This is the self-organized critical (SOC) state." An analogy of this model is used in order to introduce the reader to the game of *words* described below.

2.2 The Game of *Words*

Since the reader has been introduced to the basic notions of SOC, let us extend the SOC concept to daily life chat. We aim to show how a chat section could be consider a complex system with tendency to self-organize. Allow us explain this notion by using an analogy with the canonical example of SOC, the sandpile model as described in [4].

Supposing our system to be a chat between two interlocutors. In the beginning the chat could be considered in a flat equilibrium state, represented by the greetings from each interlocutors. As the chat evolves toward one direction - some specific topic - certain utterances may cause the course of the chat to slightly change the direction of the topic, although the initial subject still remains the same. Eventually, during the chat, there is not anything else to utter about the initial topic, so this subject can not be discussed any further, either because the interlocutors have already agreed in their ideas regarding the subject or because the topic is not any longer of interest for the interlocutors. At this point the chat has reached a stationary state where the emergent dynamics are global regarding the discussed subject. It is when, due to the communication throughout the topic - disembodiment of thoughts from the interlocutors -, a single utterance can cause the whole direction of the chat to change toward a new topic - span of the sandpile - iterating the whole process. This is the critically self-organized chat (CSOC) [8, 9]. See Fig. 1.

Let us consider for example the following chat portion between two interlocutors:

1A: Hello	39A: You hear my little niece crying
1B: Hello A, ah	39B: Heh uh Uhm so are you spring cleaning already
2A: Yes, B ah	40A: Ah intend to do it today lor
2B: Ah	

[2] Emphasis provided

Fig. 1. Critically Self-Organized Chat Cycle.

3A: Have you had your lunch
3B: No
4A: Uhm I haven't had my lunch also
4B: Uh busy uh
5A: Uhm busy playing with my nieces
5B: Both of them are in their own place
eh at your home now
....

40B: Orh
41A: So I will be home whole day lah but
41B: Uhm
42A: Uhm you know like can't get started like that do a little bit then no don't want to do uhm then
42B: Uh huh uh huh
.....

In this chat, the utterances 1A to 4B form the flat initial state of the system: greetings and topic-introductory utterances. At this point there are not big changes in the chat, it could be said the system is in *equilibrium* state. The next utterance - 5A - initiates the chat toward a determined topic: A's nieces. Although small "avalanches" may occur, i.e., the focus of the topic may be slightly changed, this topic remains the same until utterance 39B "crashes" it (catastrophic avalanche). From here a completely new topic begins: "laundry on weekends," and then the cycle repeats itself. The utterance that leads to a catastrophe - changing the flow trend of the chat - has been called "critical utterance [8]."

Let us now consider the following example:

1C: how come
1D: I don't know, I called leave messages, you don't call back for one
2C: uhm, I got your message today
2D: the other day is the day of the seminar
3C: which seminar? Oh and what did I do then, ah I can't remember I just came into the room for a few minutes and I left after that
3D: I see

4C: ya
4D: so how are you?
5C: okay, lah
5D: I've been thinking about you uh wanting to meet
6C: ya sure, aiyah, I'm so bored to death
6D: are you?
7C: sick of working and working
....

It is worth noticing that the duration of the topics does not determine the criticality of the chat. In the last example, short topics are conforming the shown chat portion (1C to 2C, 2D to 4C), however the cycle of equilibrium - evolution - shifting for each subject is observable, since a topic can be fully discussed with a small number of utterances, i.e., degree of agreement or interest of the interlocutors in the topic. It is observable that complex systems are in unity with their environment whose feedback induces their self-organization. Moreover, the emergent dynamics of the system generate criticality in order to preserve its own complexity. In the case of CSOC, it can be argued that the chat is a dynamic system whose environment is formed by the interlocutors utterances. In the same regard, the positive feedback effects that the chat flow dynamics contain might be pointed out as triggering the critical self-organization, in order to keep its own complexity. For instance, interlocutors are interested in a given topic or opinion, making the chat grow toward a certain direction. However, the growth trend is changed by a utterance given at a certain point surrounded by determined conditions (i.e., lost of interest in the discussed subject). The change may begin slowly, but it turns into a drastic revolution at a certain moment, giving birth to a new topic's trend, and the cycle iterates until the chat section is finished. This behavior has been shown to obey the Zipf's law [9].

2.3 Daily Life Criticality

Since the brain has been said to work in the self-organized critical state influenced by the external stimulus received from the environment [4, 5], it would not be out of place to ponder self-organized criticality in daily life as induced by the brain. As one of the examples of criticality in daily life we could mention, for instance, human parturition (birth). The process of human parturition has been consider to be critical process of instability where the incoherent activity of the uterus changes to a state of global coherent contractions leading to the expulsion of the baby [10].

Have the reader ever considered himself/herself as a part of the large self-organized system that the environment where we live is? - the population of cities has been shown to be critically self-organized [3, 4]! Notice how the behavior of each individual person, by itself, might have a limited impact on the system - the city - , however the juxtaposition and chaining of the behavior of many different individuals lead inexorably to triggering the criticality of the system -i.g., cities formation. Therefore, each one of us is contributing to the complexity of a system, even unconsciously.

And what to say about our personal life. The principle of CSOC where a critical utterance alters the trend of a topic might be expanded to represent critical events - important decisions - that might have a strong impact in life as to alter its growing path. This could be seen at the moment of deciding for example what is most suitable to study at the university, which in turn is more likely to affect the professional life. And what to say about decisions involving marriage and parturition, they can be seen as critical points in life that affect not only the individual person - at individual scale - but also the whole system, i.e., population of the city, -at global scale. Therefore we could see life replete by critical events, involving important things that count for our happiness, i.e., health, love and work, that in turn deeply touch the course life. When one critical event is overcome, life poises itself inevitably to another. Is this perhaps a mechanism for making us evolve - at individual scale as well as at global scale - with each equilibrium state? Could we then argue we all are programmed to behave critically? since we are within the system this fact will be unnoticeable for us. However the reflection of criticality shown in systems of human origin - formation of cities, social unrest leading to large scale strikes, traffic gridlock, and so forth - might be pointing to this conclusion.

3 Are There Chances within Criticality?

We have stated that the emergent dynamics of a complex systems are seen considering the system as a whole instead of the dynamics of each element of the system individually. From this perspective *chances* need to be consider from the point of view of the system as a whole. Therefore, we consider *chances* as part of the emergent dynamics of the system. Let us consider chances from the point of view of CSOC. It has been shown in previous sections that each topic within a chat rises from an equilibrium state to a state where the addition of a single utterance can change the direction of the topic toward a new subject of interest, iterating the cycle. From this perspective we define a *chance* as a utterance that might lead to the shifting of topics within the chat.

We could generalize this statement and argue that chances in a complex system might be represented by agents or events causing the system to alter its configuration. Those *chances* might represent risks - catastrophes - [11]. Generally, the importance of understanding those chances is outstanding in order to assess and if possible mitigate the negative consequences of the catastrophes. However their predictability is difficult due to the characteristic of complexity, self-similarity, inherent to the system itself. On the other hand, the possibility of forecasting chances in complex systems, although remains difficult, exists when considering certain phases of the evolution of those systems, i.e., the extreme events [10].

In the case of CSOC, the positive feedback effect that exists in the dynamics of chat triggers the self organization. For instance, interlocutors get interested in a given opinion, and the attraction of the topic grows according to the degree of relevance that it offers to the interlocutors. This may be regarded as similar to the Barabasi's scale free network [12]. In a scale-free network, the nodes aren't randomly or evenly connected. Scale-free networks include many very connected nodes, hubs of connectivity that shape the way the network operates, in other words, the rich grows even richer. In this regard, a topic may attract a lot of attention from the interlocutors according

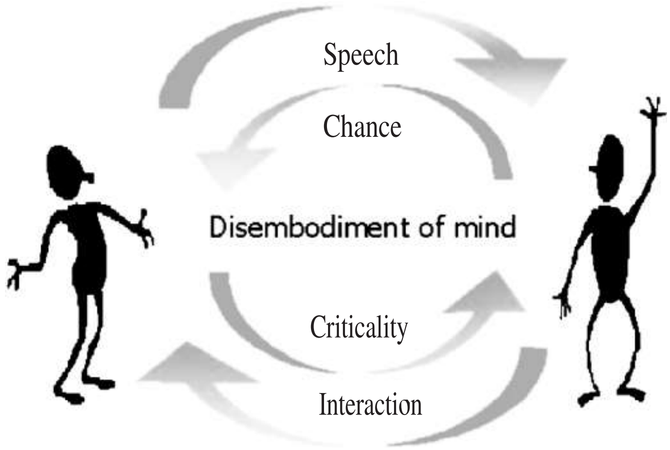

Fig. 2. Chances during disembodiment of mind.

to their individual interests, while other topics may be barely touch. However, more importantly, a sudden unexpected event may change the growth trend of the conversation. The change may begin slowly, but turns into a drastic revolution at a certain moment. It is exactly at this moment where the uprising of a critical utterance is defined. That is the moment representing a *chance* to bring up a new concern of interest coming from the natural desire of humans for a coherence in their own chat, implying a desire for self discovery, i.e., finding her/his own context of thoughts, behaviors, and chats, which might have been looking like a disordered variation. Therefore, these chances allow interlocutors the freely expression of their feelings, anxieties, i.e., disembodiment of mind, see. Fig. 2.

We could claim that the complexity of human brain has developed language as a self-organized network, and its criticality is reflected in the richness of human chat. Therefore the difficulty of modeling human *critical* chat with mathematical formulas or computer programs. However, considering the extreme events in the development of the complex system - i.e., *critical utterance* - as stated in [10], we experimented with a preliminary model of human critical chat.

A computer program that simulates human conversation through artificial intelligence is called chatbot. The dialogue model of a chatbot is based on certain word combinations that it finds in a phrase given by the user, and in the case of sophisticated chatbots, like ALICE[3] [13], AIML[4] is used to transcribe pattern-response relations. This publicly available chatbot was used in our experiments. In this preliminary model, we tried to add criticality to the

[3] Artificial LInguistic Computer Entity

[4] Artificial Intelligence Markup Language, based on eXtended Markup Language, XML

dialogue by making the chatbot to as "intelligent questions" at random points of the conversation, e.g., when a given user input did not have any anticipated response, in order to shift from one topic to a new one [14]. In order to achieve this goal, the chatbot database was enhanced with "critical categories" of general pattern-intelligent question response. The "perturbation" created by the question alters the dialogue growth trend, posing the conversation in a equilibrium state from where the dialogue rises, iterating the cycle. In a preliminary experiment, we compared the performance of the chatbot without criticality and the performance of the chatbot with criticality. Even though the changing of topics was randomly performed, the chatbot with criticality gained more attention from the user, extending the number of turns of the chat almost two times more than the number of turns with the chatbot without criticality, i.e., with the chatbot without criticality there were 48 turns of the interlocutors (user-computer) before the user gave up the conversation, on the other hand, 82 turns from the interlocutors were achieved with the chatbot with criticality, being described by the user as "more interesting to talk with."

Despite the difficulty of simulating human critical chat, i.e., making the computer use language as humans do, by simply poising questions at random points during the conversation a better simulation is possible. Isn't this what happens in daily life where at random points critical events are poised shaping in the long run our personal life?

4 Conclusions

The discussion presented has perhaps drawn our attention to the importance of our individual role in the dynamics of the complex system that our environment is. It can not be unnoticed the impact of the collective behavior of the individual elements of a complex system. Being this dynamic behavior between the system, the individuals, and the environment the source of the system complexity.

In this tradition, we have discussed the criticality of chances. Regarding chances as the agents or events that causes a self-organized critical system to alter its configuration, chances could be observe within the criticality of language, and within the dynamics of the surrounding environment, influencing our life. It could be perceived how living in a complex world replete of criticality - i.e., large earthquakes and volcanic eruptions leading to major topographic changes and severe climatic disruptions, financial crashes destroying huge amount of money affecting deeply and psychologically the investors, diseases, epidemics, traffic gridlock, and so forth - we affect this criticality by simply being part of the system, and in turn, due to the dynamics of the system, criticality shapes our personal life.

We have argued that however difficult forecasting the behavior of a complex system is, understanding what the chances are within the system is crucial in daily life decision making. Chances may appear in different flavors according to the specific situation. Taking for example our personal life. Chances may appear in the mayor bifurcations ahead us involving the important matters for our well-being, i.e., love, health, work, and the like. Therefore, being aware of this critical moments when the shape of our life is defined is of high importance. Our decisions might be the key between a chance and a catastrophe in the complex system.

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Chance Discovery

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1 Introduction

Chance discovery is an event with significant impact on human decision making a situation that has the potential for great gain as well as loss. The discovery of a "chance is to become aware of and to explain the significance of a chance, especially if the chance is rare and its significance has been unnoticed" [12]. Conceived this way, it is obvious that probabilistic methods must be combined with decision-making. It can even be interpreted in terms of the old Platonic problem of appearance vs reality, a topic that is dear to philosophers even today. But it is also the problem behind that of cognition/perception in pscyhology, and it is the same problem that occurs in the actual practice of science, and in the discussions of practice of science, e.g. epistemology. In other words, even the discussions in Philosophy of Science revolve around the problem of whether science is akin to black magic or is an efficient and competent extension of the everyday cognition and learning methods that humans employ [5].

In similar ways, one may even consider this problem as that of creativity, albeit not the ones that conventional wisdom calls creativity e.g. art, poetry etc. Scientific creativity is real creativity, and so is the cognition of the importance of events that politicians are faced with, and technological advances that CEOs must contend with in making medium term and long term decisions. Therefore it is expected that a thorough discussion must wend its way through mathematical methods of reasoning, logic, epistemology, cognition, and learning theory.

2 Knowledge

There are a set of related problems in the fields of datamining, knowledge discovery, and pattern recognition. One of them is that we don't know how many neurons should be in the hidden layer or the output layer of Artificial Neural

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Networks (ANNs) so that for clustering as a preliminary method to finding patterns we must use heuristic methods to determine how many clusters the ANN should recognize. This is just another view of the problem in datamining of knowing how many patterns there are in the data and how we would go about discerning these patterns. There is a related problem in k-nearest-neighbors clustering in which we need an appropriate data structure to be able to efficiently find the neighbors of a given input vector. Indeed, before the k- neighbors method can be used to classify an input vector we need to be able to cluster the training input vectors and an ANN might have been used for this process. The problem of knowing how many patterns (categories or classes/clusters) there are is an overriding concern in datamining, and in unsupervised artificial neural network training. Clustering, datamining, or finding patterns, is then, compression of information, which we call knowledge. And since mathematics is the study of, efficient representation, and compression of patterns, obviously, without mathematics there is no science.

Datamining is based on what was called pattern recognition. One way of classifying the components of pattern recognition is via (i) classification and (ii) estimation. Typically classification is used to create a set of discrete, finite classes, whereas estimation is taken to be an approximation of some desired numerical value based on an observation. The boundaries are not very crisp since estimation consisting of a large number of integer values may just as easily be thought of as categorization or classification. This is especially true if the measured quantities (input data) do not consist of interval or ratio-scaled values. Typically a broad-brush classification of the procedures that consist at least of parts of datamining can be strung along a continuum as shown in Fig. 1.

It may be said that the goal of datamining is to produce domain-knowledge for fields in which there are no models of the type one finds in the ultimate example of a science; physics and its derivatives. An informal listing of the classes of data mining procedures would include, Classification/Segmentation/Clustering, Forecasting/Prediction, Association Rule Extraction (knowledge discovery), Sequence Detection. Data Mining Methods may also be classified according to various criteria as: Decision Trees, Rule Induction, Neural Networks, Nearest Neighbor, Genetic Algorithms, Regression

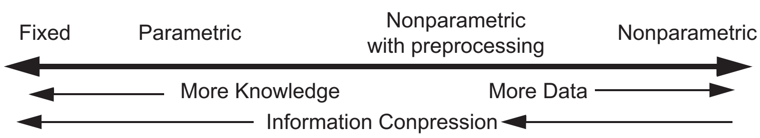

Fig. 1. The Modeling Method Continuum: Fixed models use existing knowledge on a problem(suc as in engineering). The nonparametric method relies on a large date set but does not use existing knowledge. The less-well-known aspect of a problem is captured by the nonparametric model.

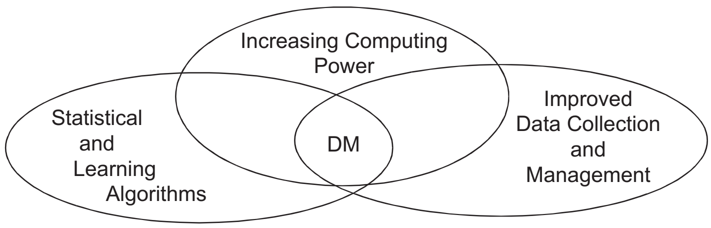

Fig. 2. Datamining Algorithms Development.

Models, Bayesianism, etc. At present datamining sits at the intersection of three broad and converging trends as shown in Fig. 2.

The Problem Space consists of: *Input dimensionality::* the number of components of the input vector; *Input space::* the set of allowed input vectors (typically infinite);*Mapping::* the model; the function that transforms/maps the inputs to the output

$$\overrightarrow{\mathrm{y}} = f(\overrightarrow{\mathrm{x}}) \tag{1}$$

where

$$\overrightarrow{\mathrm{x}} = [x_1, x_2, \ldots, x_n]^T \tag{2}$$

and

$$\overrightarrow{\mathrm{y}} = [y_1, y_2, \ldots, y_m]^T; \tag{3}$$

*Parameter vector::*a more accurate model is

$$\overrightarrow{\mathrm{y}} = f(\overrightarrow{\mathrm{x}}|\overrightarrow{\Theta}) \tag{4}$$

where $\overrightarrow{\Theta}$ is the parameter vector; and the *Learning algorithm::* generally supervised or nonsupervised learning, which fine-tune the parameters which are a part of the model.

Typically the basis of all datamining is some kind of a *clustering technique* which may serve as a preprocessing, and data reduction technique which may be followed by other algorithms for rule extraction, so that the data can be interpreted for and comprehended by humans. Prediction and classification may be a goal of the process also.

3 Clustering:: e.g. Patterns (Categorization)–Low Level Artificial Science

Clustering is the process of grouping data into classes or clusters so that objects within a cluster have high similarity in comparison with one another, but are very dissimilar to objects in other clusters. *Dissimilarities* are assessed based on the attribute values describing the objects. Often *distance measures* are used. Clustering is an unsupervised activity, or should be. Clustering can

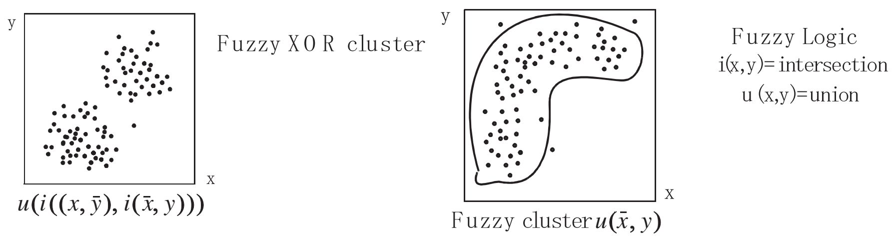

Fig. 3. 'Nonlinear' Cluster formation. The XOR kind of cluster is not linearly separable, and thus was not 'learnable' by the perceptron. This was pointed out by Minsky in the early days of neural networks and halted further research until Hopfield nets. The arbitrary shape clusters such as those above are still a problem for datamining algorithms. See for example, [7] for examples of nonlinear clustering.

be thought of as the preprocessing stage for much of datamining. An automated clustering algorithm may be said to be the goal of datamining since *classification* and *prediction* algorithms can work on the clusters. Similarly *association rules* may be derived from the clusters. Clustering can be used by marketers to discover distinct groups of buyers in their customer bases. It can be used to derive taxonomies in biology or linguistics. It can help categorize genes with similar functionality, and classify WWW documents for information discovery. In other words, it is a tool to gain insight into the distribution of data. It has been a branch of statistics for years. In machine learning it is an example of unsupervised learning. In datamining active themes for research focus on scalability of clustering methods, the effectiveness of methods for clustering of complex shapes, and types of data, high-dimensional clustering techniques, and methods for clustering mixed numerical and categorical data in large databases. Requirements for an ideal clustering procedure can be found in [6], and these capabilities can be inferred to exist in human beings, where they are performed by neural networks.

The memory-based clustering procedures typically operate on one of two data structures: data matrix or dissimilarity matrix. Every object is a vector of attributes, and the attributes may be on various scales such as nominal, ordinal, interval or ratio. The d(j,k) in the *dissimilarity matrix* is the difference (or perceptual distance) between objects j and k. Therefore d(j,k) is zero if the objects are identical and small if they are similar.

4 Mathematics of Belief (Cox-Jaynes Axioms)

We are at a point where we can begin to make sense of what science is, how it is to be done, and how reasoning takes place. Intelligence (of our kind, e.g. human kind) is embodied in the brain. The mind is what the brain does. Sensory impressions (data) are always coming in. The brain/ mind is always categorizing/recognizing things. It is when it starts to fail that we start to

Table 1.

Scalability	The procedure should be able to handle large number of objects, or should have a complexity of O(n), O(log(n)), O(nlog(n)). Human sensory systems seem to handle inputs logarithmically.
Ability to deal with different types of attributes	The method should be able to handle various levels of measurement such as nominal (binary, or categorical), ordinal, interval, and ratio. Infants start to learn to categorize objects (implicitly using measurement), then learn to name them, then we teach them about arithmetic, and formal reasoning (mathematics) later. Theoretical work in datamining is about the mathematics (formality) of how the human brain accomplishes these tasks.
Discovery of clusters with arbitrary shape	The procedure should be able to cluster shapes other than spheroidal which is what most distance metrics such as the Euclidean or Manhattan metrics produce. Humans can recognize all kinds of patterns. (See Fig. 3)
Minimal requirements for domain knowledge to determine input parameters	The method should not require the user to input various "magic parameters". Human infants, indeed all living things start learning from the environment immediately. Our (scientific,formal, mathematical) knowledge of different domains comes after many years of study.
Ability to deal with noisy data	The method should be able to deal with outliers, missing data, or erroneous data. Certain techniques such as ANNs seem better than others. Over hundreds of thousands of years we have been able to finally get a clear view of nature, via the scientific method, despite all the noise in the signal.
Insensitivity to the order of input records	The same set of data presented in different orderings should not produce different sets of clusters. Unfortunately, this does not seem to be true for humans; what we learn first affects our learning because of brain plasticity.
High dimensionality	Human eyes are good at clustering low-dimensional (2D or 3D) data but clustering procedures should work on very high dimensional data. The extension to higher dimensions cannot be done without formal mathematical models and training.
Constraint-based clustering	The procedure should be able to handle various constraints. Here, too, humans seem to excel; we have been able to find patterns in life and "use" them taking into account the constraints imposed by laws of nature.
Interpretability and usability	For practical purposes (bare minimum, for most people) this means that the results such as association rules should be given in terms of logic, Boolean algebra, probability theory or fuzzy logic. Any mathematics we can use is by definition 'comprehensible' in some sense.

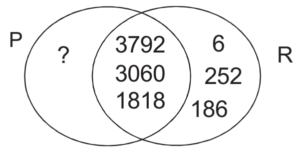

Fig. 4. Suppose we enter the integers 3792, 3060, and 1818. What do we want? What would you predict? How do we generalize? How do we learn (e.g.) via examples?

realize that what is apparently true (for the brain/mind) may not be true in reality. The same problem occurs in science; what folk physics says may not be what physics says. This interplay between appearances and reality have been the bane of philosophers since Plato's metaphor with the cave, and are the stuff of optical illusions psychologists study even today. Forced binary discrimination tests are conducted by psychologists to try to analyze perception at the detail level and similar ideas are used there. In this section we will look at the use of crisp logic, fuzzy logic and Bayesian reasoning.

At one time IBM was using a database system and method of searching called query- by-example (QBE), in an attempt to teach people natural ways of searching databases. QBE is both a query language and the name of a DB system including it. Something similar occurs when a child learns a language or when we search Google by entering some words or phrases. Google 'predicts' what is meant (e.g. appearence) and tries to make it match reality (what we really want). In real life we may never completely know reality. That is also the quandary that science finds itself in. In science, as in logic, truth is provisional; only falsehood is definite. Datamining is the quintessential kernel of science in that it tries to group data into clusters so that each member in the cluster resembles other members of the cluster more than it resembles other objects. That is what categorization is about, the lowest level of measurement. Even animals are capable of clustering and categorization. Much of this is done implicitly and informally in most living organisms. Such informality is unforgiveable in doing science even if not in writing for the masses.

Suppose, P is what Google predicts in response to a query by a user who really wants all the articles in the set R (reality). Then the cases (see Table 2) 00 and 11 are correct; and the cases 01 and 10 are errors. The case 00 corresponds to all articles the user did not want and did not get; 11 is the intersection of P and R, and consists of webpages the user wanted and got. Suppose we give an HIV test to millions of people and P is the set of people whom the test "predicted" have HIV; after all no test is perfect. The cases 00 and 11 are interpreted as above. The case 01 is called False Negative (FN) because the test predicts that the subject is negative but is not. Similarly 10 is False Positive (FP) because the test claims that the subject is infected but is not. Which error is more costly to society?

Similar conundrums bedevil society at all levels of decision-making.

Suppose these sets represent the people that the justice system claims are criminals, say murderers. Which error is worse? With all due respect to

Justice Holmes, a justice system that lets go 1000 murderers (FN) for every single FP is not a good system at all. Suppose the people being let go are terrorists bent on destruction. Is it a good idea to let 1000 of them escape? The same decision problem plagues police officers every day. The same decision problem plagues common people every day. People must make judgements based on appearances every day, and pay for the FPs and FNs every day. So it is especially with relationships, friendships, and beliefs about society. Shall we allow all kinds of harmful beliefs (say, Marxism of the worst kind) be propagated by the alleged elite at our universities subsidized by our tax dollars. Is this kind of decision-making not the essence of science? We have to make a mental shift from certain knowledge (things like $1 + 1 = 2$) to probabilistic truths. Many things which we may believe are true may not be true.

It is possible to treat belief systems with the rigor of mathematics. We can reason about reasoning. The result is the Cox-Jaynes axioms. The explanation below closely follows the exposition in Baldi & Brunak (1998). A hypothesis H about the world is a proposition, albeit a very complex one composed of many more elementary propositions. A model M can be viewed as a proposition. In the nonmathematical world the model M would be called a "theory". Since models have many parameters we may consider M=M(w) where w is a vector of parameters. We really wish to reason in the face of uncertainty. Thus we consider that given a certain amount of information I, we can associate with each M a degree of plausability or confidence, or degree of belief (DoB), B(X|I). Now, for any two propositions X, and Y either we believe X more than Y or vice versa or we believe both equally. Therefore we write

B(X|)>B(Y|I)

if we think that X is more plausable than Y. It is clear that the relationship (>) should be transitive. Formally, this is Cox's first axiom:

$$B(X|I) > B(Y|I) \wedge B(Y|I) > B(Z|I) \Rightarrow B(X|I) > B(Z|I) \qquad (5)$$

This means that DoBs can be expressed as real numbers and thus ">" is an ordering relationship. Therefore B(X|I) represents a real number, even if such a number is not easy calculate. For the next axiom consider the belief in the proposition B($\bar{\mathrm{X}}$|I) Where $\bar{\mathrm{X}}$ is the denial of the hypothesis. It is easy to see that the more confidence we have in B($\bar{\mathrm{X}}$|I) the less confidence we should have that the denial B($\bar{\mathrm{X}}$|I) is true. This belief of ours should be true for all such statements. Thus, in mathematical terms, we say that there exists a function so that

$$B(\bar{X}|I = f(B(X|I)) \qquad (6)$$

Notice that we have not given the form of the function F that specifies how the two propositions should be decreasing functions of each other, merely that they should be related to one another somehow. Certainly, it makes sense that as we believe X more and more, we should believe NOT(X) less and less. Later, how this decreasing function should be incorporated into the

Cox- Jaynes axioms will be made explicit, The third axiom considers pairs of hypotheses;

$$B(X \bullet Y|I) = g(B(X|I), B(Y|X, I)) \tag{7}$$

Where the $\bullet$ sign indicates a logical-AND. In other words, our degree of belief that X is true, and our belief that Y is true, for example, depends on our belief that X is true, and that Y is true knowing that X is true. Now, I is the conjunction of all the available pieces of information. It can represent background knowledge; it can include specific experimental data or other data. When it is necessary to be specific we can write I=I(D) to denote dependence on a corpus of data D. It is not really fixed and can be augmented by other symbols or even dropped when it is well-defined. These three axioms determine, up to a scaling, how to calculate DoBs. It can be proven that there is always a scaling of degrees of belief such that DoBs can be constrained to [0,1] e.g. a function P(X|I)=k(B(X|I))

Furthermore it can be shown that P(X|I) is unique and that is satisfies all the rules of probability. Specifically, if *DoB* is restricted to the interval [0,1] then the functions F and G must be given by f(x) = 1-x and g(x,y) = xy.

In this case, the DoBs can be replaced by probabilities. It should be noted that f(x) is really like the fuzzy-negation, and g(x,y)=xy corresponds (in some fuzzy logics) to a logical-AND or intersection. As a result the second axiom can be written as the sum rule of probability theory e.g.

$$P(X|I) + P(\bar{X}|I) = 1 \tag{8}$$

This is simply the probabilistic equivalent of the Law of the Excluded Middle in logic that goes back to Aristotle. The third axiom is the product rule, e.g.

$$P(X \bullet Y|I) = P(X|I)P(Y|X \bullet I) \tag{9}$$

These DoBs can simply be replaced by probabilities. By using the symmetry one can then obtain the important Bayes theorem

$$P(X|Y \bullet I) = \frac{P(Y|X \bullet I)P(X|I)}{P(X|I)} = P(X|I) \cdot \frac{P(Y|X \bullet I)}{P(Y|I)} \tag{10}$$

This rule implies inference-learning since it describes how to update our degree of belief P(X|I) in X, in light of the new pieces of information provided by Y, to obtain the new P(X|Y $\bullet$ I) Because of this P(X|I) is called the prior probability and P(X|Y $\bullet$ I) the posterior probability. Obviously the rule can be iterated as many times as needed as new information becomes available. It should be noted that there is a more general set of axioms for a more complete theory that encompasses Bayesian theory. These are the axioms of decision theory or utility theory which focuses on how to make optimal decisions in the face of uncertainty. The simple axioms of decision theory allow the construction and estimation of Bayesian probabilities. An even more general theory, game theory, considers the case where the uncertain environment includes other intelligent agents or players. In dealing with nature, we assume that nature does not change its tactics to oppose us as we discover its laws hence Bayesianism is more or less sufficient. In a more specific setting, we are most interested in deriving a parameterized model M=M(w) from a corpus of data D. Dropping I for simplicity, the Bayes theorem gives.

$$P(M|D) = P(M) \cdot \frac{P(D|M)}{P(D)} \tag{11}$$

The prior P(M) is our estimate of the probability that model M is correct before we have obtained any data. The posterior P(M|D) represents our updated belief in the probability that model M is correct given that we have observed the data D. Indeed, this is more or less what doing science is about. There is more on this topic, namely being able to compare models to one another such as using the Akaike information criteria (AIC), or MDL (minimum description length) or EM (expectation maximization); these can be found in books on datamining, and artificial intelligence. It is easy to see that M is appearance/prediction (e.g. our model/prediction of reality) and that D represents (information/data or reality). We now have a way of reasoning precisely using beliefs, probabilities, logic and fuzzy logic, and creating simple (fuzzy-logical) models of various aspects of reality.

5 Hempel's Problem Revisited with Measurement

Hempel's Raven paradox involves the 'confirmation value' of empirical evidence in the logic of epistemology. The statement "Ravens are black" (e.g. R $\Rightarrow$ B) via the contrapositive is "equivalent" in logic to "If x is not a raven, it is not black" (e.g. $\bar{\mathrm{B}} \Rightarrow \bar{\mathrm{R}}$). Therefore, if a raven that is black "confirms" the statement R $\Rightarrow$ B, then a red banana confirms the same statement via the contrapositive. These are the problems one runs into when attempting to do probability theory via binary logic. There are four possibilities when faced with a perception/cognition problem or a generalization problem (see Fig. 5 or Fig. 6 below). Perception/cognition, typically as discussed in philosophy and psychology consists of 'naming' objects e.g. categorization. The simplest form of it is the "Forced Binary Discrimination Test" often used in psychology to analyze cognition. This process itself can be explained in terms of a nonlinear differential equation [8]. "Truth" (degree of truth?) depends on the relative sizes of the various sets shown in Fig. 6. We are back to Plato's Problem (e.g. Fig. 5).

Clearly, the regions marked 01 and 10 are errors where the appearance does not match reality. The case 01 corresponds to black nonraven things which are weak confirmation. The case 10 corresponds to ravens that are not black and is the counterexample to the generalization. Certainly this is definite nonconfirmation. We want region 11 to be high because that confirms

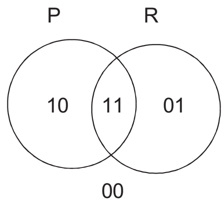

Table 1:

Appearance	Reality	Judgement	
0	0	Good	
0	1	Type I Error	False Negative (FN)
1	0	Type II Error	False Positive (FP)
1	1	Good	

Fig. 5. Plato's Problem: Appearance vs Reality. How science is done using simple crisp logic and sets. The terms False Negative and False Positive are especially useful in medical testing.

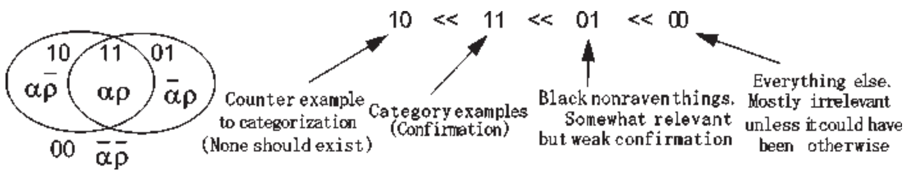

Fig. 6. Here α is used for "apparent" and ρ for "real" in order to prepare for developments below.

APPEARANCE \ REALITY	0 negative	1 Positive
Negative 0	$B(Apparently\ False\ \vert\ Really\ False)$	$B(Apparently\ False\ \vert\ Really\ True)$
Positive 1	$B(Apparently\ True\ \vert\ Really\ False)$	$B(Apparently\ True\ \vert\ Really\ True)$

Fig. 7. Belief (probability) of Appearance and Reality.

the generalization. In Fig. 6 we see the general sizes of the various categories that we expect in the real world. The type 00 is the largest category and its confirmatory value is almost zero. Then as an initial starting point we should want 11/01 to be high and 10/00 to be high. Therefore we should try to maximize something like (11/01)(10/00). Or we might want to deal with the fractions (11/ [11+01]) and (10/[10+00]). The former is the fraction that is correct[true] of the total correct[true]. The second is the fraction that is incorrect[false] out of the total that is incorrect[false]. Can we change our reasoning so that we can make better decisions?

For normal reasoning these do not obey things like the laws of probability theory because they are beliefs and we cannot make these computations on the fly. So we can define

$$\tau = \frac{B(\alpha|\rho)}{B(\alpha|\rho) + B(\bar{\alpha}|\rho)} = \frac{1}{1 + \frac{B(\bar{\alpha}|\rho)}{B(\alpha|\rho)}} = True\ Belief Fraction \tag{12}$$

$$\Phi = \frac{B(\alpha|\bar{\rho})}{B(\bar{\alpha}|\bar{\rho}) + B(\alpha|\bar{\rho})} = \frac{1}{1 + \frac{B(\bar{\alpha}|\bar{\rho})}{B(\alpha|\bar{\rho})}} = False\ Belief Fraction \tag{13}$$

But the fraction τ is $\frac{11}{11+01}$ or $\frac{1}{1+01/11}$ and the fraction Φ is $\frac{10}{00+10}$ or $\frac{1}{1+00/10}$. Minimizing (01/11) will maximize τ and maximizing (00/10) will minimize Φ. Therefore, minimizing (01/11)*(10/00) will optimize τ/Φ which is what we want, if the costs are equal. If not we should take into account costs. But there is already a developed theory based on conditional probabilities using the Bayes Theorem. The True Belief fraction is called sensitivity, and the False Belief Fraction is 1-specificity. These terms are from medical terminology of FN and FP.

6 Hypothesis Testing and Receiver Operating Characteristics (ROC)

Suppose some event has occurrred. We have to decide whether it is important (valuable opportunity e.g. "chance" for great gain of some sorts) or that it is worthless. It corresponds to making a decision as to whether something is real or fake (an impostor opportunity). Given some kind of a score, or measurement, classification (into real truth vs apparent truth, etc) involves choosing between two hypotheses: that the apparent oppportunity is real, or fake. Let H0 be the hypothesis that the chance is fake, and H1 be the hypothesis that the chance is real. Suppose we are given the measurements from two different pdfs according to whether the chance is real or fake as shown in Fig. 8.

In Table 2 we see the various possibilities. It is clear that the True Belief Fraction is really the sensitivity of the test, and the False Belief Fraction is the FPR (false positive rate). Table 2 summarizes the possibilities.

The hypothesis determines over which pdf to integrate, and the threshhold, T, determines which decision region forms the limits of integration. Let $p(z|H_0)$ be the conditional density function of the score z generated by false-chance events, and let $p(z|H_1)$ be the conditional pdf for true/ real chance events. If the true conditional pdfs of fake and real chances are known, then

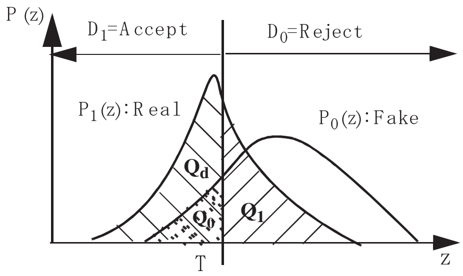

Fig. 8. Statistical Inferencing Scheme for ROC The probability density functions of real and fake (false) chances or opportunities for gain of some kind. (see Campbell or Metz).

Table 2.

Performance Probabilities	Decision D	Hypothesis H	Name of Probability	Result	Explanation
Q_0	1	0	Size of Test "Significance"	Type I Error	FP False Acceptance
Q_1	0	1		Type II Error	FN False Rejection
Q_d=1-Q_1	1	1	Power of Test		True Acceptance
1-Q_0	0	0			True Rejection

the Bayes test with equal misclassification costs is based upon the likelihood ratio for the decision- maker A, $\lambda_A(z)$

$$\lambda_A(z) = \frac{p_A(z|H_0)}{p_A(z|H_1)} \tag{14}$$

The probability of error, which is minimized by Bayes' decision rule is determined by the amount of overlap in the two pdfs. The smaller the overlap between the two pdfs, the smaller the probability of error. If the true conditional pdfs score densities for the good-decision-maker vs the bad- decision-maker are unknown, the two pdfs can be estimated from sample experimental outcomes. The conditional pdf given a good decision-maker A, $p_A(z|H_1)$ can be estimated from the decision-maker's own scores using his model. The conditional pdf for bad-decision-makers, $p_A(z|H_0)$ is estimated from other decision-makers' scores using the A's model. Once the likelihood ratio for A, $\lambda_A(z)$ can be determined, the classification problem can be stated as choosing a threshold T so that the decision rule is

$$\lambda_A(z) \begin{cases} \geq T & \text{choose } H_0 \\ < T & \text{choose } H_1 \end{cases} \tag{15}$$

One of the ways in which the threshold T can be determined is by varying T to find different FA/ FR (FP/FN) ratios and choosing T to give the desired FP/FN ratio [2]. Since the either of the two types of errors can be reduced at the expense of an increase in the other, a measure of overall system performance must specify the levels of both types of errors. The tradeoff between FP and FN is a function of the threshold. This is depicted in the ROC (receiver operating characteristic) curve. In the example by Campbell, it is assumed that the product of the probability of FP and the probability of FN is a constant for this system (which is not true in general) and is equal to the square of the equal error rate (EER). In the example by Metz, the ROC curve is the one in which the sensitivity is plotted against the false positive fraction which is 1-specificity. It comes from the area of statistical analysis, specifically, medical testing. A test is given to determine if a person is sick with a given disease; such a person is said to be positive. These are clearly related to the False-Positive (FP) and False-Negative (FN) results of statistical testing. Now, it is not clear at all that tests give constant results, or that FP is linearly related to the FN. Specifically, in medicine, Sensitivity and Specificity of each test depend on the particular "threshhold of abnormality" adopted for that test. Some tests have higher Sensitivity but lower Specificity than the other. Perhaps we should maximize specificitysensitivity or something like it.

With tests we are stuck with what tests can do. Similar comments can be made about psychological tests, and informal judgements people make which are based on heuristics. The reason the above analysis is not sufficient is that there will be built in biases against and for truth vs falseness. For example, there are loss aversion bias, status quo bias, hindsight bias, bias towards positive and confirming evidence, and others which have been studied [see for example, [10]]. These biases will be a function of socialization and knowledge capability. In the same paper a simulated example is given of the computations for various thresholds as shown in Fig. 9.

We can see that... the cost itself can be treated as a fuzzy variable so that the final result resembles something like a an fuzzy XOR. There are many

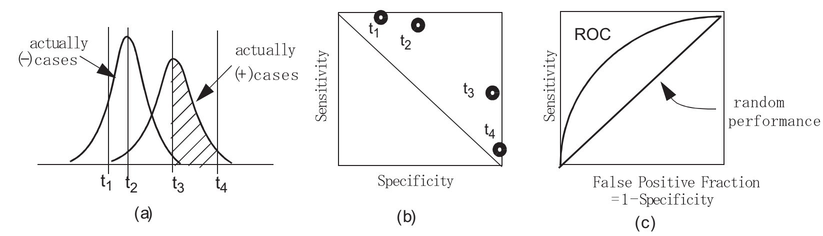

Fig. 9. Simulated Results from Metz. In (a) we see four simulated positions for the 'anomaly'. The resulting points on the plot of sensitivity vs specificity is shown in (b). A curve is swept out as the threshold of abnormality (T) is varied continuously (c) and compared against "random" guessing (straight line).

other kinds of problems that resemble this. Consider now the interpretation of Eq. (12a) which describes, say, results of a forced binary test

$$\frac{P}{1-P} = \tau \tag{16}$$

where $\tau = K/D$, P=Pr(correct answer), K=knowledge, and D=problem difficulty. This result can be considered to be a special form of Rasch modeling, which is given by

$$\begin{aligned}
&\pi = \frac{e^{\lambda}}{1+e^{\lambda}} \\
&\text{or} \\
&\frac{\pi}{1-\pi} = e^{\lambda} \\
&\text{where} \\
&\lambda = K - D \\
&\text{and} \\
&\pi = \Pr(\text{correct answer})
\end{aligned} \tag{17}$$

For a simple case such as a binary test, P can easily be interpreted as the TPR, and $1-P$ is the FPR. Consider the case $\tau = 0$ (when the knowledge of the individual is 0 or if the problem is of infinite difficulty), then clearly $P = 0$. Now, if the difficulty is 0, then we consider the equation $\{1-P\}/P = 1/\tau$. Clearly, then $1-P = 0$ or $P = 1$. For an interpretation of $K = D$ consider the case of a match between two boxers of exactly equal capability. The probability of either of them winning should be 0.5, and this is the case with this equation. Therefore it is clear that, for someone randomly guessing at the solution (binary choice) we'd expect a linear relationship between τ and Φ,

$$\tau = f(K/D)\Phi = f(\kappa)\Phi = \kappa\Phi \tag{18}$$

Anything better than random guessing would be a curve above the straight line at 45 degrees and anything below would be worse than random.We can derive the typical ROC curve (which is derived via some assumptions) by assuming different values of κ and therefore something like a piecewise linear relationship between τ and Φ. Specifically, suppose sets of questions at different difficulty levels were given to students. For each set of questions we'd expect different values of τ and Φ. Since we know the difficulty levels, we can compute the corresponding K values (see Fig. 10). Now for a multiple choice test, we can apply the same interpretation. Indeed, this would be the ideal way to grade tests. Someone operating in, say, a business environment making decisions at a technical level as to whether a given development in the field is a great "chance" with a potential bonanza for the company would be faced

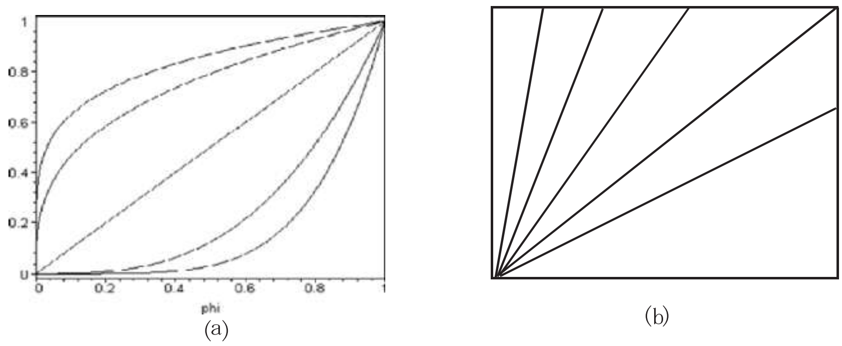

Fig. 10. The curve given by for various values in $\tau = f(k)\Phi^{1/f(k)}$. For values of $1/f(k) > 1$ we obtain the curves below the random guessing line. For a linear relationship e.g. $\tau = k\Phi$, obviously we get the straight lines in (b). These must be considered to be linear approximations of a more complex nonlinear reality.These curves can be related to learning theory (see below).

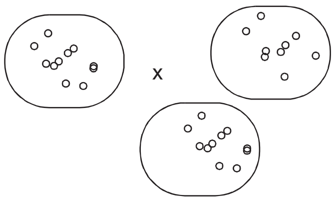

Fig. 11. Chance Discovery Problem and [In]formal Datamining.

with a similar problem. We can designate the function $f(\kappa)$ as the knowledge function, or the competence function. For example, via theoretical reasons we may assume other functional forms such as

$$\tau = f(\kappa)\Phi^{1/f(\kappa)} \tag{19}$$

These latter ones will result in curves as shown in Fig. 10.

7 Categorical Measurement

There are errors in measurement and judgement. There could be confusion in perception and categorization so that only nominal (categorical level) of measurement may be possible and the person making that decision may make errors in judgement. The person might hold inconsistent beliefs e.g. X +Not(X) is not equal to 1. There may be biases in belief e.g. folk-belief may interfere totally with Cox-Jaynes axioms. Here we cannot find a measurment along a single dimension so that the ROC curves explained on the bass of the threshold T, may not be possible. A picture (Euler diagram, as in Fig. 11) can be used to explain what we might be able to do in such a case. A discovery, (or fact/information) X, could possibly have big consequences (e.g. a chance). Its evaluation (apparent value) depends on the knowledge of the discoverer, but its real value is not known. It can be miscategorized. It might be fit into one of the clusters (say, a branch of mathematics), or it may be used to connect the two branches or even all three areas into a complete more comprehensive theory. This process is a part of the continuous generation and production of [scientific] knowledge.

Suppose the values possible are: worthless (W), valuable (V), and priceless(P). These would correspond in Fig. 11 to (i) not connecting X to anything, (ii) connecting X to one of the clusters, and (iii) connecting X to all three clusters and thus joining all three fields together in a new theoretical finding. These 'fields' may be cross-disciplinary or in a business setting they may cross the boundaries of conventionally different branches of business.It is possible to convert this into something like the Likert Scale (and use ordinality) and therefore relate this to the concept of a threshold as above, but here we leave the categories as they are and make assumptions about the capabilities of the reasoner.

The analysis below closely follows that of [14]. The overall probabilities with which the various possibilities (e.g. chances) are judged are $\boldsymbol{\pi}_W$, $\boldsymbol{\pi}_V$, and $\boldsymbol{\pi}_P$. The probability that a true possibility of type T is believed as a possibility of type t is denoted as R(T|t) (e.g. R(real|apparent). We set this equal to $1-\gamma$ for a correct observation, and $\gamma/2$ for either of the possible wrong judgments. The idea can be used for multiple-choice tests. For example, the probability that a valuable possibility will appear to be valuable is R(V, V) = 1 - γ, and the probability that a valuable possibility will appear to be worthless is R(W, V) = 1 - $\gamma/2$. The probability P(T|t) that the true type is T when the observed (apparent) type is t is P(T|t)=P(T_t)/P(t). For example, the probability that a type which appears to be worthless is in reality worthless is

$$\begin{aligned} P(W|W) &= \frac{R(W|W)\pi_W}{R(W|W)\pi_W + R(W|V)\pi_V + R(W|P)\pi_P} \\ &= \frac{(1-\gamma)\pi_W}{(1-\gamma)\pi_W + (\gamma/2)\pi_V + (\gamma/2)\pi_P} \end{aligned} \tag{20}$$

The probability that the chance which appears to be priceless (extremely valuable) opportunity is in reality valuable is given by

$$\begin{aligned} P(P|W) &= \frac{R(P|W)\pi_W}{R(P|W)\pi_W + R(P|V)\pi_V + R(P|P)\pi_P} \\ &= \frac{(\gamma/2)\pi_W}{(1-\gamma)\pi_W + (\gamma/2)\pi_V + (\gamma/2)\pi_P} \end{aligned} \tag{21}$$

The case for N categories is simply a generalization of these equations

$$P(C_n|C_m) = \frac{R(C_n|C_m)\pi_{C_m}}{\sum_m R(C_n|C_m)\pi_{C_m}} \tag{22}$$

It should be recalled that for each decision maker the probability of making the correct identification is fixed at $R(C_k, C_k) = 1-\gamma$, and the probability of making the wrong identification is distributed equally so as to maximize the entropy. In cases in which there is some dimension along which some measurement(s) can be made these probabilities could be distributed according to a pdf along this dimension, which would then make this more like the ROC; for this we would need a concept of distance (see below).

8 Summary

1) The classical ROC (the one shown above) is based on signal detection, and thus the Gaussian assumption. The integral leads to solutions in terms of the error function, erf(T), or erfc(T) so that explicit (and simple) algebraic equations are not possible. It would be better in many ways if simpler equations were used, if for no other reason than pedagogical purposes. For example, a uniform density (which would be better in some cases) would produce easily comprehensible algebraic equations. A triangular density (an approximation to Gaussian) would also produce easily manipulatable algebraic quantities. This is shown in Fig. 13.
2) The ROC method as shown actually hides the fact that the relative positions of the error pdf and the true signal pdf are fixed (e.g. to the right or left). In reality, in complex situations, even if presented within the ROC framework, the decision-maker has to make a decision as to the relative positions of these pdfs and that itself is not a part of the ROC method except implicitly.
3) With some simplifying assumptions the categoricity of the last section can be turned into the threshold framework (with ordinal, difference or ratio levels of measurement) of the 'classical' ROC shown earlier. The main problem is that the "distance" measure cannot be represented along a single dimension as in the graphs shown. Instead, we might have to use something like a graph-theoretic measure on complete graphs. For example, the Likert scale would require a K5 (Kuratowski graph) complete graph of 5 nodes. Each incorrect edge (4 of them) would/could be given a weight (distance) of $1/\gamma$. If we tried to use the ROC analysis as above, we'd have to (i) index the categories and create

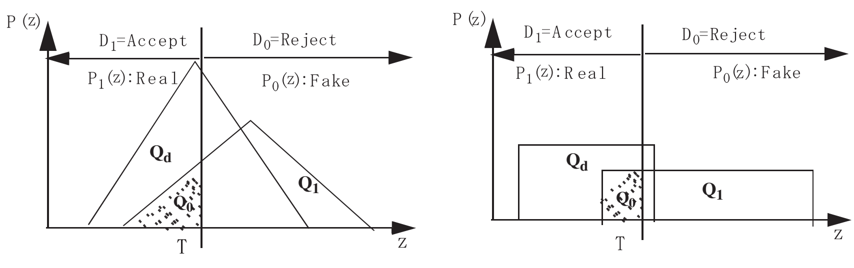

Fig. 12. Pedagogical Simplification of the ROC Analysis.

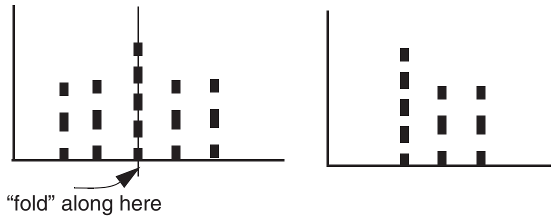

Fig. 13. Categorical Bayes and Distance.

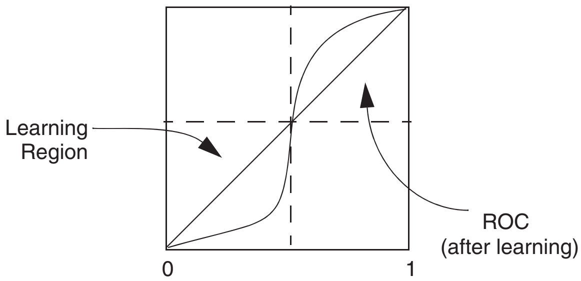

Fig. 14. ROC and Learning Theory. It should be noticed that the abcissa is a 'normalized T' and thus the classical Verhulst curve will not work.

some kind of a distance/similarity measure, or (ii) use a "folded" distance e.g. Fig. 13.
4) The ROC method itself should be a part of learning theory. See Fig. 14.

During learning where the learner has many choices, there's a high probability of false positives since we learn from errors (negative feedback). This is the part of the curve in the first quadrant. Obviously the axes would have to be normalized so that the Verhulst curve would have to be fixed up (e.g. normalized). Ditto for the related Rasch curve which is specifically related to measurement of competence. And this would also be used in testing in both a school setting and in informal testing of competence in various fields especially of artificial agents since they do not suffer from psychological needs.
5) A more sophisticated (future) approach would extend this so that 'knowledge' can be defined more clearly, especially domain knowledge that is required to make good decisions. Only hints have been given here. Obviously, it would be most easily done in the case of scientific (mathematical) knowledge. In cases where information is significant, multiple choice questions would be used.
6) The ROC results can easily be explained in terms of fuzzy-logic. Even if for no other purposes than pedagogical, it would be extremely useful to so do. Indeed some of the equations above are easily explicable and comprehensible in terms of fuzzy logic. Sensitivity and specificity are basically complements.

Plotting both against normalized-T would lead to two curves resembling supply and demand curves of economics (e.g. tradeoff). The normalized product basically the Beta density. If the costs of false positives and false negatives are equal the function is symmetric and can be considered the analog of the Gaussian in normalized [0,1] space. If the costs are not equal, the result is skewed in one of the directions. In either case, the function can be treated as an *fdf* (fuzzy density function). In other words, the costs of correct and incorrect decisions have not been incorporated. They can also be incorporated so as to depict the problem as an optimization problem which would be more appropriate for a business or economic setting, and since ultimately analysis has to be justified in terms of economic costs and benefits, this line of research should be pursued.

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Scenario Maps on Situational Switch Model, Applied to Blood-Test Data for Hepatitis C Patients

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1 Introduction: Scenarios and Chances

Automated learning of frequent patterns from sequential data with a computer can be used for understanding typical episodes in medical cases [1, 2, 3, 4]. An episode implies the existence of an underlying context, due to a causal situation or a set of causal events. However, an expert sometimes also needs to know *scenarios*, i.e., possible sequences of episodes occurring in a significant context, if his/her real-world domain is so complex that thinking of a fixed situation is not meaningful enough. For aiding such an expert, we have been developing a method for visualizing bridges between frequent situations, meaning the switches from/to episodes.

In this chapter, a scenario map for the progress/recovery of hepatitis C is visualized with *KeyGraph*, where episodes and bridges between episodes is shown based on a causal model with three layers of events on the observability of events. This shows (1) a scenario map clarifies admissible scenarios of the progress of and the recovery from hepatitis C, from legacy data on blood tests, and (2) the proposed causal model of situational switching suits the aid of discovering the scenarios of hepatitis progress/recovery. The respective effects of interferon, iron, etc., and their positions in the scenario of treatment appeared in the obtained scenario maps.

2 Scenarios and Chances in the Basis of Decision

Chiba University Hospital has been storing the data of blood-tests for their 771 patients of hepatitis, from 1982 to 2001 [5]. In each blood test, the values of a part of the 456 given variables were measured. We cleaned these data in the way shown below, and, as a result, we chose 71 variables.

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1) Variables, of which the upper and the lower bounds were predefined, were chosen from the 456 variables.
2) The values of ions such as K+, Ca2+, Cl-, etc, were deleted because the meaning of these various is ambiguous - they can be the results of drugs not relevant to hepatitis.
3) A value in an unexpected type, e.g., an alphabetical symbol for a numerical variable, or a variable without its value was ignored because it is meaningless.
4) Values recorded in different units such as [mg/dl] and [mg/l] were unified into the description on the same unit.
5) When the recorded value was more than 1000 percent of the upper bound or less than 10% of the lower bound, the value was cut off from the data because the value can be likely to be an error.
6) Extraordinary values or extraordinary changes in the values of corresponding variables, are translated into symbols. That is, "X_Y" means a discrete state where the value of variable X took the value or the change as Y shows in 'H' 'L' '+' or '-'. For example, D-BIL_H (L) means a state where the value of D-BIL, i.e., direct bilirubin, was higher (lower) than the predetermined upper (lower) bound of the normal value range of D-BIL. And, D-BIL_+ (-) means the value of D-BIL increased for two sequential tests.
7) Some variables are redundant. For example, jaundice was identical to T-BIL_high (total bilirubin over its upper bound). Then the value was translated into the value of a numerical variable, i.e., to T-BIL_high.
8) Symbols meaning events which can not be represented by variable names, such as "interferon" meaning the use of interferon for treatment, were inserted. Items denoting these treatments were also included in the lines of blood tests (one line in Eq. (1)) during the period of treatment. On the other hands, items corresponding to the type of hepatitis, i.e., A, B, or C, which were included in the blood-test data as diagnosed results were used for extracting the data relevant to research concern. In this chapter, we focus on cases of hepatitis C.

As a result, we obtained 284 items (i.e., symbols), and translated the overall data set into the form as in Eq (1), where one line corresponds to one time of blood test.

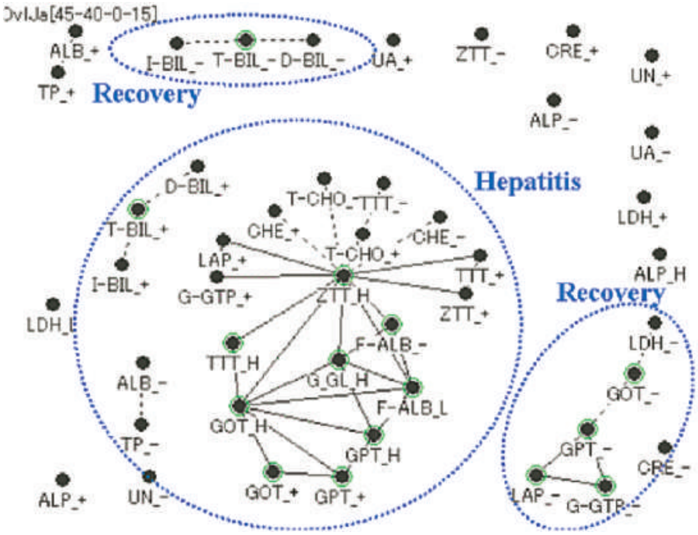
$$\begin{aligned} D = \;& \text{CHE\_- GPT\_H GOT\_H ZTT\_H} \ldots, \\ & \text{Interferon ZTT\_H GPT\_H GOT\_H G-GPT\_-} \ldots, \\ & \text{G-GPT\_- GPT\_- CHE\_+}, \\ & \ldots, \end{aligned} \tag{1}$$

In the data, we notice the difference of frequencies of items. The importance of a low-frequency item is hard to be noticed, and such an item tends to appear less frequently due to the weak attention of the observer (doctor decides variables of blood test data, when he/she sees a patient). Because the switch from one episode to another tends to occur in a short time, its frequency in the data comes to be low. As a result, bridges are hard to be recorded in the data. Even worse, the importance of such a rare event is hard to explain on data using a computer, because the scenario before and after such an event is uncertain. This problem, in other words, is to predict the future to occur from a rare event, and is different from predicting rare events which have been studied recently in [6, 7].

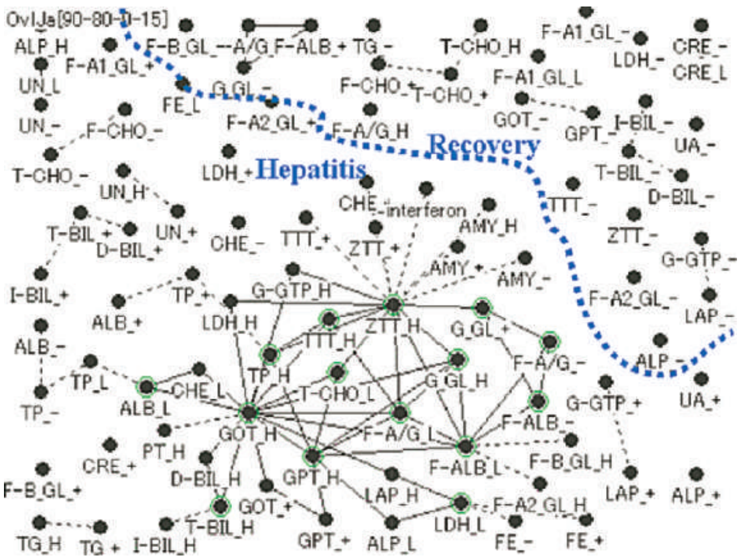
3 Potential Methods for Visualizing a Scenario Map

Methods for clustering and visualizing data can be useful for showing a scenario map, i.e., a map of episodes and the bridges between episodes, from a data set in the form of Eq. (1). Clustering methods (See [8, 9] for survey) separate events into clusters, each including events strongly relevant to each other. A frequent episode can be shown as a cluster, if the relevance between events is defined on their co-occurrence, i.e., the frequency of lines including those events. See Fig. 1 for the result of clustering based on Jaccard coefficient for the liver data. We also doubled the number of links between nodes, from 40 in Fig. 1 to 80. However, only the links in each cluster became denser and the bridges among clusters did not appear. The clusters tend to stay similar even if we increase the links, as far as the same measure of relevance has been used.

Some clustering methods deal with events corresponding to bridges between clusters [10], but they aim at cutting bridges for obtaining well-organized clusters rather than interpreting the meaning of bridges. Seeing another approach, in the correspondence analysis [11], the events in the data are mapped into a 2-dimensional space where the closeness between events reflects the co-occurrence between them. The user is expected to infer the meaning of the vertical and the horizontal axes from the output figure, and achieve the macroscopic understanding of the environment. However, the quantity of information of relations between all pairs of events is in proportion to the square of the number of events N, whereas the information expressed by the positions of all events in the figure is 2N (the value of X and Y for the position of each event). Due to this loss of information, the relation between clusters, i.e., of bridges disappears much from the output. In our application to the data of blood tests, the bridges between clusters were never understood from the visualized positions of items with these previous tools.



(a) 40 relations among 45 blood states



(b) 80 relations among 90 blood states

Fig. 1. The result of clustering on the co-occurrences between variable values, for the same data to be dealt in Fig. 3, i.e., 9314 blood tests of representing hepatitis C cases. The links present the results more informatively than the locations of items. Yet the switches to/from the progress and the recovery of hepatitis do not appear even if the number of nodes and links is doubled ((a) to (b)).

4 KeyGraph with episodes and bridges

4.1 KeyGraph with time-sequence arrows

In order to overcome these problems, the scenario map is desired to introduce a new measure of the relevance between clusters, different from the measure for computing the relevance of items in each episode. It is also desired that the links between items and between clusters are explicitly visualized in order to avoid the problem in correspondence analysis. Because we may have many clusters corresponding to frequent episodes and links corresponding to bridges between episodes, we here take the approach of chance discovery, where episodes and the candidates of bridges between episodes are visualized, so that the user can select understandable and meaningful bridges from the map.

Here we chose *KeyGraph* ([12, 13], and Chapter 1 of this book) as the method for visualizing scenario maps. In KeyGraph, as stated in Chapter 1, frequent events are shown in black nodes, and a black link connects a pair of black nodes co-occurring frequently. A co-occurrence here means two events occur in close positions in the data. Each cluster then includes a set of events corresponding to a frequent episode. An essential shift from/to episode, via the occurrence of a rare event, is depicted by a red node and two red links bridging the red node and two clusters co-occurring strongly with the red node. These red nodes depict bridging multiple clusters in Eq. (1).

We presented the first version of *KeyGraph* in 1998 [12], for extracting keywords from a document by substituting each "event" below with a "word" and each set of events with a "sentence" for Step 1 and Step 2 below. This worked in the case when a word significant for the content structure of the document is of low frequency. Adding Step 3, we made scenario maps here from *KeyGraph*. By applying *KeyGraph* to earthquake sequences [13], we found this tool can show signs of big events. That is, the frequent words in each cluster co-occur with each other frequently. And, rare words co-occurring with multiple clusters show bridges between the clusters.

[The Procedure of KeyGraph (Step 3 is a specific device for hepatitis analysis)]

Step 1 (Episodes in KeyGraph): The most frequent $M1$ events appearing more frequently (e.g., "GPT_H" in Eq. (2)) are depicted with black nodes, and $M2$ pairs of such frequent events co-occurring the most frequently in the same set (i.e., in the same set ending with a period) get linked with a solid black line. For example, GOT_H, GPT_H, and ZTT_H in Eq. (1) are connected via black lines as in Fig. 3. Each connected graph here forms one *cluster*, implying a basis of scenario, i.e., events in a frequent episode. Weak links are cut, i.e., an arbitrary line X is pruned if the nodes on its two edges lose connection without X.

Step 2 (Episode bridges in KeyGraph): Events co-occurring with multiple clusters, e.g., interferon in Eq. (1), are obtained as *hubs*. A path of links connecting islands via hubs is called a *bridge*. If a hub is rarer than the black nodes, it is colored in a different color (e.g. red or white) than black. We can regard such a new hub as an event which may be rare but significant for episode-to-episode jumping decisions.

Step 3 (Arrows for Scenario Directions): For showing the time-serial relations, i.e., order of events, thick arrows are attached if the order of two events is significant. For example, an arrow is attached from GPT_- to GOT_-, if a sequence of two times of GOT_- occurred after the same pattern of GPT_-, for more than 70% of the occurrences of .both GPT_- and GOT_-within 10 sequential blood tests. As a result, a scenario of typical chronological course is expected to appear as a connected path of arrows.

4.2 Definitions of Co-occurrence in KeyGraph

The co-occurrence of item U and V is defined by Eq. (2), Eq. (3), or Eq. (4) according to the choice of the user.

$$overlap(U, V) = p(U \text{ and } V)/min(p(U), p(V)) \tag{2}$$

$$Jaccard(U, V) = p(U \text{ and } V)/p(U \text{ or } V) \tag{3}$$

$$mutual(U, V) = p(U, V)/p(U)p(V) \tag{4}$$

The overlap (i.e., Sympson's) function in Eq. (2) means the larger of the two conditional probabilities to be computed between U and V. Suppose a cluster of events corresponds to an episode, where an event is caused by its precedent event, an overlap value means the conditional probability from a cause to a result in the episode. The Jaccard's function in Eq. (3) means the ratio of the length of transition period from U to V compared to the length of all time U or V occurred. Finally, Eq. (4) means the inverse of the prior probability of the common cause C of U and V. That is, expressing the conditional probability of C by p(C), U is A and C, and V is B and C for some hidden events A and B. Thus

$$p(U) = p(A)p(C), \quad \text{and} \quad p(V) = p(B)p(C),$$

which derives

$$p(UandV) = p(A \text{ and } B \text{ and } C) = p(A)p(B)p(C).$$

As a result, $p(U \text{ and } V)/p(U)p(V)$ in Eq. (4) is equal to $p^{-1}(C)$.

In this chapter, computing the co-occurrences, we consider three layers of events in the causality model in Fig. 2. This model means the cause T of the situational switch is triggered by its requirement, i.e., required by a previous event S. S can be an event not included in the data, and is supposed to occur from a cause common to events in the preceding situation A. For example, T means a medical treatment or an immunochemical reaction for overcoming V+, a hazardous external influence, e.g. a virus, causing a set of symptoms in situation A.

The effect of T is V-, extinguishing the effect of V+ and leading to stable B of recovery. We also consider uncertainty, i.e., the existence of conditions to restrain or enhance reactions. Corresponding to these conditions, we put C1 through C7 in Fig. 2. We find {A, T} and {T, B} are related via V+ and T respectively, which are the common causes of each pair. Thus, we can say the relations between A and T, and between T and B, are to be represented by the mutual information of {A, T} and {B, T} respectively, if their relations are via hidden common causes.

These coefficients have been popular in measuring the similarity between words for information retrieval [14]. Causality models on Bayesian networks also show causal relations between events due to hidden events [15, 16]. However, introducing the layers of events reflecting the human perception of events, as in Fig. 2, is novel and important in the complex real domain such as medical treatment.

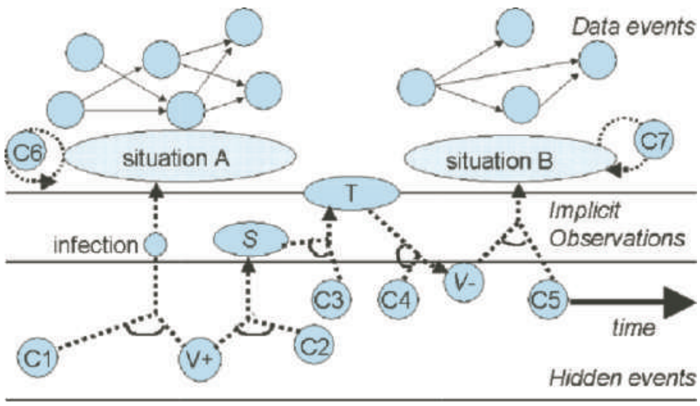


Fig. 2. Three-layered causality model. The highest layer is of events observable and recorded in the data. There can be some clusters in this layer, the events in which are frequent and the causalities between which appear as frequent patterns in the data. Such a cluster is visualized by black nodes and black links in KeyGraph. The second layer is also of unobservable events, but not to be recorded in the data because the set of variables in the database is limited. In the case of medical application, a doctor may look at these events and reflect to their treatment decisions. The third layer is of events not observed but are fundamental causes of higher layers.

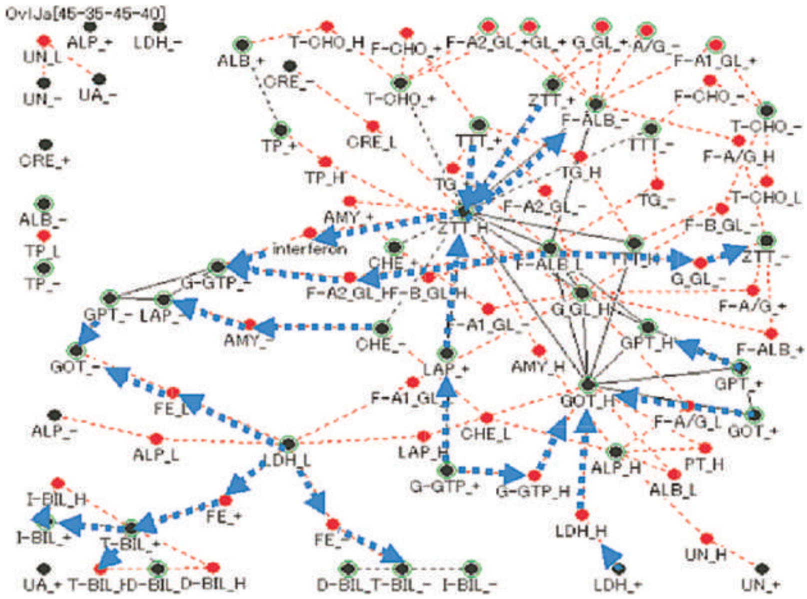
5 Two outputs of KeyGraph, on different measures of co-occurrence

Reflecting these semantics of Eq. (2) to (4), the strength of co-occurrence between U (a node) and V (a node or a cluster) was computed on two settings. In setting (A), the co-occurrence between nodes was given by the transition probability, i.e., the overlap co-efficient, and the co-occurrence between a node and a cluster was given by the Jaccard's. In setting (B), the latter co-occurrence was given by the mutual information.

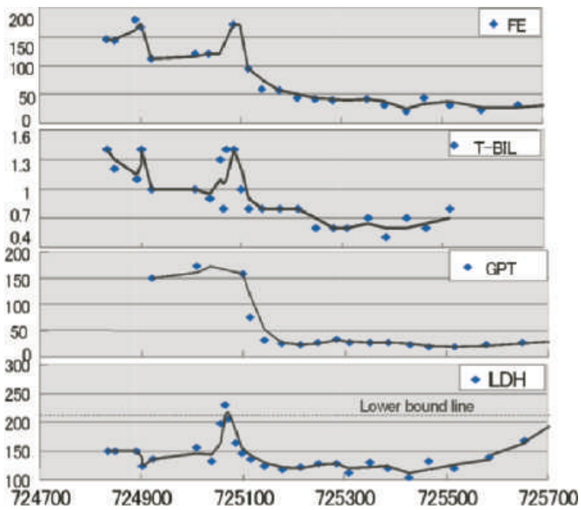
Figure 3 is the result of KeyGraph obtained for the data set of 64 patients of hepatitis C who experienced radical decrease in iron, i.e., same as in Fig. 1, in the setting of (A). The large (right side, including GPT_H) cluster of black nodes and black links correspond to an event-cluster in the top layer of Fig. 2, because they are frequent events connected by large conditional (transition) probabilities. In this cluster, prevalent blood-test results for hepatitis progress such as GPT_+, GOT_H etc. are shown out. This frequent episode, and another episode of recovery (left side, including GPT_-), are connected via the bridge meaning the treatment with interferon. The occurrence of this treatment is rarer than events in the two clustered episodes, but represents an essential transition of states.

In this scenario map, we find two significant bridges relevant to the quantity of iron. One is the low value of iron (FE_L), and the other is the decrease in iron (FE_-). The decrease in iron (FE_-) correlates with the decrease in bilirubin, whereas the low value of iron (FE_L) tends to appear before the decrease in GOT and GPT, as in the case of interferon treatment. This supports the evidences that iron reduction, i.e., omitting a portion of blood from the body to clean the iron stored in the liver, helps interferon treatment [17]. For the 63 patients who experienced FE_L after GPT_high, 100% reached GPT_-, a sign of recovery. A novel finding was that T-BIL (total bilirubin) has been the most sensitive to the changes in FE as supported in figure (b) of Fig. 3. For 273 blood tests including FE_-, T-BIL_- was found to occur 98% simultaneously, whereas GOT_- and GPT_- occurred 58% and 60% respectively. These values mean the following things: (1) the increase in iron is due to the melting of blood, which releases iron and also bilirubin from hemoglobin [18]. As well, the decrease in iron means the omission of blood aiming at iron reduction, which also decreased the chance of the release of bilirubin. These causalities has not been reported based on real data so far.

Figure 4 is the result of KeyGraph under setting (B). This result was obtained for the focused data on blood-tests including LDH_low (LDH: lactate dehydrogenase). I made this focus because interferon and other items corresponding to treatments were not shown in (B) for the larger data used in Fig. 3, but LDH was shown to exist in the process from the situation of hepatitis progress to recovery (The peak LDH level signals the beginning of recovery and the subsequent normalization of the platelet count, which is said to be a condition for interferon to work normally [19]).



(a)



(b)

Fig. 3. The scenario map for hepatitis C, on the 9314 blood tests for 64 patients who experienced FE_- and FE_L. The curves in (b) show changes in the values of variables of the blood. The increase in ALP, following the decrease in FE, GOT, and ALP, corresponds to the scenario map in (a). The increase in T-BIL with the increase in FE as in (a) corresponds to the curves in (b).

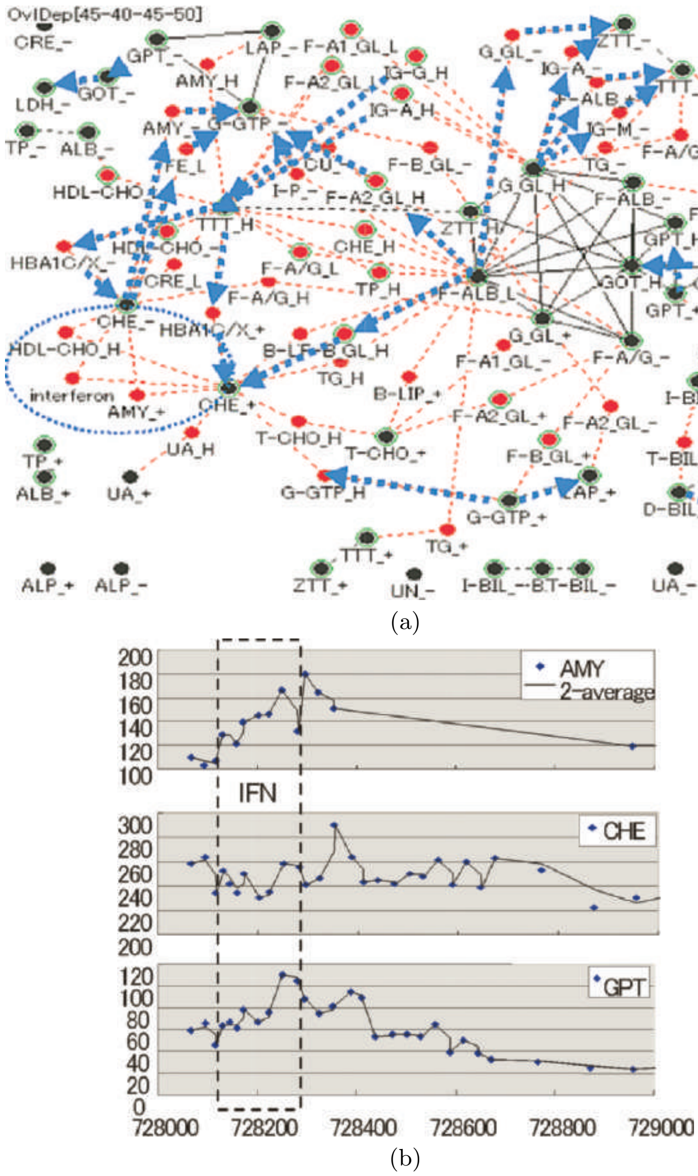


Fig. 4. Scenario map for patients at the time of FE_L (left), and the co-variation of iron with LDH, amylase and gamma GPT (right). Amylase tends to increase and LDH stay low, when FE_L affects on the recovery of liver.

The reason why items for treatments did not appear in the graph in this setting is that the causality considered in Fig. 2 could not be caught on the Jaccard co-efficient. Thus, I changed to use mutual information for computing the links bridging clusters. That is, the bridges corresponding to the second and the third layers in setting (B). That is, I assumed a treatment does not really effect if the situation is not focused on a suitable situation although it may appear between the two situations just as a superficial fact.

This visualization in Fig. 4 reveals events being affected by interferon (see the dotted circle). It begins from high fraction of B-GL (b-globurin, including Transferrin, a protein supporting the metabolism of iron), and AMY_+ (increase in amylase) plus the improvement of HDL cholesterol are observed to occur with the effect of interferon appearing between CHE_+ and CHE_-. In fact, as in (b) of Fig. 4, choline esterase (CHE) responds quickly to interferon, with the trembling of its value. For 73% of cases using interferon, CHE decreased shortly before the effects of interferon and responded to interferon quickly by similar trembling followed by its increase. FE_- is found to affect after the treatment with interferon, and amylase finally decreased before the obvious signs of recovery such as GOT_- and GPT_-. For 46% of cases with interferon and FE_- these recovery signs appeared, whereas the rate was 28% for cases treated with interferon.

Another finding in Fig. 4 is that immunogloburins (IG_A, IG_M, and IG_G), meaning the attack from HCV virus which affects to the progress of disease, do not decrease with this process of recovery, even though interferon should have killed virus. This implies that interferon only kills a part of all virus, and works by being combined with the effects of other factors against virus [20, 21, 23, 24, 25]. In this data-set, iron reduction compensates for the effect of interferon. There is also the directed path from interferon back to the progressive state in Fig. 4, corresponding to the reported side effects of interferon treatments [26, 27].

The method with implementing the causality models to *KeyGraph* in making a scenario map is not fully automated, in that the number of visualized nodes and links are given manually and the data is focused on the concern of the user. This freedom for the user is beneficial in arranging the granularity of the output, for seeing the details desired for understanding a certain state of the patient. This ease in paying attention to a part of the map helps in understanding some switches between stable situations from a small part of the scenario map. In this chapter, I exemplified this in discovering major scenarios to the recovery of hepatitis C.

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Uncertainty Reasoning and Chance Discovery

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Summary. Chance discovery is one of the hottest issues and various computational methods are applied to solve the problem. It inherently contains uncertainty because it is based on the human's concept and sometimes hard to define clearly. In this domain, it is very important to model human's uncertain knowledge easily and provide manipulation method for the intervention of humans in the knowledge discovery. Recently, Bayesian network that is a symbolic model with flexible inference capability has gained popularity from various domains. In this paper, we present the possibility of Bayesian network for chance discovery in terms of uncertainty reasoning, and show some of the applications such as detecting chances from system, application and concept levels.

1 Introduction

Chance discovery is to recognize a chance which is a very rare event, but with significant impact on decision making or future change [18]. It gives not only an awareness of chances but also an explanation about chances. This approach has been applied to various applications domains such as predicting earthquake, discovering new topics from WWW, and agent communication [1, 3]. First of all, let us discuss about the relationships between chance discovery and uncertainty reasoning.

Recently, uncertainty handling for chance discovery has gained interest with many different approaches such as neuro-fuzzy [20], probabilistic logic [19], qualitative methods [18], and rough sets [17]. Because chance is a rare event, computers have a difficulty to deal with it. In fact, the cooperation of human knowledge and computational algorithm is important to detect the chance. Also, usually chance is considered as something connected with randomness and measured in probability [18]. Therefore, representing human's uncertain knowledge and statistical prior knowledge in a formal inference/prediction model is one of critical problems to deal with uncertainty for chance discovery. There are various sources of uncertainty in chance discovery.

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- Human: Human is one important component for the success of chance discovery and he has inherent uncertainty. It is difficult to guarantee that his interpretation of provided evidence from computer will be exact. Also his concept about chance is not clear to capture because of vagueness and uncertainty.
- Data: Data could have contradictions. Most of data tell general trends but some of them indicate very rare cases that are significantly opposite compared to the trends. It can be interpreted as a uncertainty because it could has many different results given the similar situation because of hidden effect or inter-relationships among variables. In traditional data mining, data deviated significantly from general trends are considered as a noise but in chance discovery, they are considered as valuable sources for chance and ignoring them must be avoided.
- Chance: Sometimes, chances are defined deterministically but it is not true in many real world situations. Given the same situations, it is unclear that the chance would come true. It can be defined as a concept of probability or degree. Also, the definition of chance has uncertainty. Its boundary that defines chance is not clear and some fuzzy or rough method is needed.

There are various methods to deal with uncertainty such as fuzzy logic [12], rough sets [13], probabilistic models [14], and hybrid of them. They are all very important method to represent uncertainty in chance discovery and they are not competitive but complementary. In this paper, we would like to introduce a variety of criteria for uncertainty handling models in chance discovery and Bayesian networks, one of the representative models in probabilistic models, in details. Bayesian networks are frequently used to model complex cognitive functions of human and show successful results in various applications [21]. The most important decision criteria for uncertainty handling model of chance discovery are easy construction of model with learning algorithm, flexible inference capability with missing variables in two different directions (forward and backward), interpretability and easy manipulation of model for the interaction of humans, and sound mathematical foundations.

- Learning: Basically, chance discovery is a kind of intercommunication process between human and computer because chance is very difficult to identify. Computer supports human by providing evidences about chance from massive dataset using mining algorithm. Its purpose is not to discover general trends of data set but to notify unknown or novel important factors that result in great phenomenon. Though human's role in this procedure is critical, it is natural that doing such task without computer's help is impossible because of huge size of dataset. Therefore, the capability of learning model from the dataset is one of criteria for uncertainty handling and its nature is a bit different from the traditional one in the classification or prediction domain. Because it discovers very rare significant event, showing only good classification or prediction accuracy is not always desirable. Instead of increasing classification accuracy for one effect, it is necessary to model accurate global joint probability distribution that embodied rare events. It is well known that describing an exact joint distribution probability given several variables is not possible due to the huge storage space requirement with a number of parameters. Bayesian network is an acyclic directed graphical model that represents joint distribution probability of random variables. By ignoring irrelevant conditional dependencies among variables, it approximates true joint probability distribution with a small number of parameters. Learning Bayesian networks are well studied for several years and one can easily construct Bayesian networks for this massive dataset.

- Flexible inference: One requirement for chance discovery model is an ability that can deal with novel or unknown situations. Rules are one of the easiest and good choices for modeling trends in massive dataset but it has a critical weakness. In the perspective of uncertainty handling, rule is quite deterministic and cannot deal with contradictions that are critical to model chance discovery. Of course, it is possible to do such thing in the framework of rules with some additional effort (defining weights for each rule or maintaining separate rule set for chance discovery) but it is not competitive compared to other methods that have such capability inherently. Also, rule has a difficulty to model unknown situation (conditions). If rule-set cannot cover all areas of condition space, it cannot provide results for previously unknown conditions. Defining rules manually is very difficult job given a number of variables and it is not surprising that some situations are not defined because of limited information and designer's mistake. Furthermore, accurate description of condition space results in a number of rules. Because Bayesian networks represent joint distribution probability of random variables, it is not necessary to describe conditions for specific results and it can provide evidences for any combinations of variables.
- Missing variables: Chance discovery is related to discover hidden cause-effect relationships that lead to great success or risk. If it has a form of simple cause-effect, rule-based approach can perform well but it is not true. In many cases, some causes might generate great effect and its relationship is difficult to describe in a simple cause-effect form. Its relationship is not direct but indirect one. In the route from cause and effect, there are a number of paths and its length is larger than two. The effect of causes is propagated through indirect links of a number of random variables and finally it results in change of effect variables. In the worse case, some relevant variables can be missing. If there is only a set of condition-results rules, it has a difficulty to provide results given some missing variables. Because Bayesian networks are based on the network structure and probability propagation algorithm to infer the probability of effect, such situation can be easily solved. In the case of missing, it can generate results robustly because the inference algorithm can deal with such situation naturally.

- Bi-directional inference: If there is very successful case or risk, it is interesting to infer the conditions that make it possible. We call it as backward inference. That means uncertainty handling methods require a flexibility of evidence-query setting. Sometimes evidences can be query and the opposite side must be possible. Fuzzy rules that are very useful tool to deal with human's perception in the form of if-then rules need to define additional rules to deal with such cases. If there is enough knowledge about the domain in the form of if-then rules, fuzzy rules can be very good choice but doing backward inference given known results is not easy to do. In the case of Bayesian network, any node (variable) can be query or evidence nodes and there is no restriction. Domain expert can analyze the probability of unobservable evidences given known results (great success, risk and general situation) using backward inference and the knowledge can be used to refine the model to improve the performance of chance discovery.
- Interpretation: Connectionist models such as neural networks for uncertainty handling has a weakness because they are very difficult to understand for human. Domain experts need to analyze the automatically learned model and their inference flow to guess the success or risk of future. For improvement, understanding the model is very important. In this reason, a model like keygraph is preferable because it provides easily understandable visualization of model [1]. Like keygraph, Bayesian networks are based on the graph structure and it is easy to visualize. Each edge of the network represents cause-effect relationships (conceptual relationships) and human expert can understand the whole procedure of inference from cause and effect. One of the successful application areas of Bayesian network is medical area and its reason is that various relationships from doctors knowledge have a form of cause-effect. If a domain has enough cause-effect relationships, complex phenomenon for chance can be easily visualized in the form of network of cause-effect relationships.
- Manipulation: Ohsawa defined the procedure of chance discovery as continuous interactions of human and computers [1]. That means continuous revision of the model is also needed. After understanding the model, human expert could modify the model to represent his belief about chance. If the modification is very difficult, the interaction of computer and human may not be desirable. Modifying rules is relatively easy because it is based on the simple condition-results. The modification of condition parts immediately results in desirable results. However, modifying one rule need to check occurence of contradiction with all other rules. On the other hand, modifying Bayesian network can be thought as an easy process but sometimes it can be difficult because it is based on indirect relationships. Because their edge is based on cause-effect relationship, modification is just procedure of adding/deleting edges with parameter tuning. In case of Bayesian network, there is no guarantee that modification of specific edge can results in desirable one. Because it models joint distribution probability, change of small modification can change the distribution and it can

make unexpected results. Basically, modifying the model is not difficult but tuning the joint probability distribution as you want is a bit difficult. Recommendation for this situation is re-training the parameters of the changed model from accumulated data. However, it is one integrated model compared to rule sets, contradiction check is not necessary.

- Mathematical foundation: Uncertainty handling methods have sound mathematical definition. Their original research was based on mathematical theory and after several years it was applied to many real-world applications. Because of the relatively short history, there is little research for the mathematical foundation of uncertainty handling for chance discovery. It might be better to adopt previously well-defined method in other domains and refine the model for chance discovery. The mathematical foundation of Bayesian networks are from probability theory and its sound mathematical formulation allows researchers focus on more advanced topics.

Bayesian networks use probabilities and assume that it cannot know everything. That allows them to capture subtle behaviors that would require thousands of strict rules [4, 5]. Horvitz et al. propose the construction of Bayesian networks that provide inferences about the probability that subjects will consider events to be memory landmarks based on the intuition that rare contexts might be more memorable than common ones [16].

In this paper, we show some possibilities of the Bayesian networks to detect various chances from middleware reconfiguration (low level), object detection (middle level), and common-sense modeling (high level). In the low level, the knowledge about the rare event is not easily defined by human because of the complexity; it is easy to learn the detection model from data. In the middle level, there are a number of data and also limited knowledge about intermediate concepts. It might be better to model the network with hybrid of learning and modeling by experts. In the high level, there are few data for conceptual situation, and it might be better to model such cases only by human experts.

In middleware, a system fault is relatively rare event and detecting it from various uncertain (due to distributed computing) information sources is a quite challenging. Detecting the critical problem and acting properly based on the prediction is one of the significant decision problems for adaptive middleware. In the framework of component-based middleware, the decision of reconfiguration of components is inferred based on the probabilities from automatically learned Bayesian networks.

Detection of rare objects from visual scene for service robot is one of the interesting applications of chance discovery. Some critical objects such as dangerous toxic, broken cups and unknown things are very important for security, surveillance, and elderly care. In this paper, activity-object Bayesian network is presented to deal with occluded objects and reduce modeling cost [7]. Finally, modeling commonsense for context-awareness of service robot based on Bayesian network is illustrated with hierarchical organization of a number of models. By modeling unexpected situations using probabilistic models, it can detect chances that are crucial to make natural interactions between human and computer [6].

2 Bayesian Network for Chance Discovery

Many researchers think of the Bayesian network as a useful tool for handling uncertainty. Given partially observed variables, BN can give a concise specification of any full joint probability distribution. The design variables or the environmental parameters are subject to perturbations or deterministic changes. It is very common that a system to be optimized is expected to perform satisfactorily even when the design variables or the environmental parameters change within a certain range. If some of variables become unobservable suddenly, conventional optimized solutions might be out of orders. However, probabilistic reasoning tool can deal with such situations naturally without additional effort such as re-optimization. Moreover, BN provides the system designer with cost-effective method of a structural refinement because it is based on a symbolic representation which is easily understandable.

Bayesian probabilistic inference is one of the famous models for inference and representation of the environment with insufficient information. The node of Bayesian network represents random variable, while the arc represents the dependency between variables [8, 9]. In order to infer the network, the structure must be designed and the probability distribution must be specified. Usually the structure is designed by expert while the probability distribution is calculated by expert or collected data from the domain. By observing evidence, the probability of each node is computed by Bayesian inference algorithm based on the conditional probability table and independence assumption.

We use $< B, \Theta_B >$ to denote a Bayesian network with a structure B and probability parameters Θ_B. $P < B, \Theta_B >$ denotes the joint probability distribution of all the variables of this network. A Bayesian network is a directed acyclic graph $B = (V, E)$, where the set of nodes $V = \{x_1, x_2, ..., x_n\}$ represents the domain variables and E, a set of arcs, represents the direct dependency among the variables. For each variable $x_i \in V$, conditional probability distribution is $P(x_i|Pa(x_i))$, where $Pa(x_i)$ represents the parent set of the variable x_i.

$$P < B, \Theta_B >= P(x_1, x_2, ..., x_n) = \prod_{i=1}^{n} P(x_i|Pa(x_i)) \tag{1}$$

Recently, some researchers attempt to deal with uncertainty in Bayesian network learning and modeling. Kim et al. adopt expandable Bayesian network (EBN) for computing 3D object descriptions from images [10]. One challenge in the problem is that the number of the evidence features varies at runtime

Table 1. Joint probability distribution for V(T=True, F=False)

x_1	x_2	x_3	$P(x_1, x_2, x_3)$
T	T	T	P_1
T	T	F	P_2
...	...	...	...
F	F	F	$1 - \sum P_i$

because the number of images being used is not fixed and some modalities may not always be available. It uses repeatable and hidden nodes to deal with the uncertainty. Lam proposes a new approach to refining Bayesian network structures from partially specified data [11].

2.1 Basic Definition

If there are n random variables and they have binary states, the total number of parameters for a joint probability distribution of n variables is $2^n - 1$. For example, V has three random variables x_1,x_2, and x_3. The joint probability of the variables is $P(x_1, x_2, x_3)$. To describe the probability distribution, 7 parameters are needed. Table 1 summarizes the parameters and values of the variables.

If all the parameters for the joint probability distribution are determined, any kind of queries can be calculated using the distribution. For example, $P(x_1 = T)$ can be calculated by the sum of $P_1 + P_2 + P_3 + P_4$. If there is prior knowledge about the domain, the posterior probability of some variables can be calculated using the Bayes rule.

$$P(x_1|x_2) = \frac{P(x_1, x_2)}{P(x_2)} = \frac{P(x_2|x_1)P(x_1)}{P(x_2)} \tag{2}$$

If the values of some variables are known, it is possible to infer the probability of the states of the unknown variables. For example, the value of variable x_i is known as True but the values of x_2 and x_3 are unknown. The probability of x_2=True and x_3=True given A=True is defined as $P(x_2 = T, x_3 = T|x_1 = T)$. Using the Bayes rule, this can be calculated as follows.

$$P(x_2 = T, x_3 = T|x_1 = T) = \frac{P(x_2 = T, x_3 = T, x_1 = T)}{P(x_1 = T)} = \frac{P_1}{P_1 + P_2 + P_3 + P_4} \tag{3}$$

This means that the probability of the unknown variables can be calculated (given some unobserved variables) without additional effort. This flexibility allows robustness of inference against sudden input missing.

In the formula, the variable x_1 is called an evidence variable and x_2 is a query variable. If the value of x_2 is known and the query variable is x_1, the probability of the query is as follows.

$$P(x_1 = T|x_2 = T) = \frac{P(x_1 = T, x_2 = T)}{P(x_2 = T)} = \frac{P_1 + P_2}{P_1 + P_2 + P_5 + P_6} \quad (4)$$

In fact, any variables can be called query nodes, and the probability of these query nodes can be calculated. For example, suppose that there are 3 relevant input variables and 1 chance variable in a chance discovery system. Each input variable, respectively, is denoted by x_1,x_2, and x_3. If the system observes x_1=True, x_2=True but no information x_3, the probability of chance $P(x_4)$ can be calculated as follows.

$$P(x_4 = T|x_1 = T, x_2 = T) \quad (5)$$

If there is no chance, the probability of x_3 can be calculated as follows.

$$P(x_3 = T|x_1 = T, x_2 = T, x_4 = F) \quad (6)$$

This flexibility of inference is very useful in domains with uncertainty. The classification of query and evidence nodes is not clear and some variables have the possibility of sudden loss of information (unobservable). However, there are practical problems for such inference because of the large number of parameters when working with a large number of variables.

Figure 1 shows a simple BN with 5 variables and 4 edges. This means that (x_1, x_3), (x_2, x_3), (x_3, x_4), and (x_3, x_5) are conditionally dependent. $P(x_1, x_3, x_4, x_5)$ is as follows.

$$P(x_1, x_2, x_3, x_4, x_5) = P(x_1)P(x_2)P(x_3|x_1, x_2)P(x_4|x_3)P(x_5|x_3) \quad (7)$$

This calculation needs only 10 parameters instead of $2^5 - 1$. These parameters are $P(x_1 = T), P(x_2 = T), P(x_3 = T|x_1 = T, x_2 = T), P(x_3 = T|x_1 = T, x_2 = F), P(x_3 = T|x_1 = F, x_2 = T), P(x_3 = T|x_1 = F, X_2 = F), P(x_4 = T|x_3 = T), P(x_4 = T|x_3 = F), P(x_5 = T|x_3 = T)$, and $P(x_5 = T|x_3 = F)$. Each child node contains conditional probability parameters. By assuming conditional independence between variables, we can ignore some parameters. The ALARM network, a well-known benchmark BN, has 37 variables and each variable has $2 \sim 4$ states. The number of parameters of the network is 590 instead of 2^{54}.

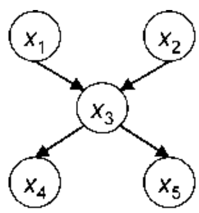

Fig. 1. A simple Bayesian network

2.2 Learning

If there is enough domain knowledge and an expert can summarize this knowledge into a cause-effect form, it can be easily converted into BNs. However, this kind of expert knowledge is only available in popular domains such as medicine and trouble-shooting. Understanding and predicting the behavior of computer systems is very difficult because of the dynamic and complex interactions of modules within the system. To develop appropriate BNs for this specific problem given a little prior knowledge, learning is essential. Learning BNs are composed of two stages: structure and parameter learning. Using a scoring function that returns a numerical value for the appropriateness of the given data in the BNs, search algorithms such as greedy and genetic algorithms attempt to maximize the score.

In order to induce a BN from data, researchers proposed a variety of score metrics based on different assumptions. Yang et al. compared the performance of five score metrics: the uniform prior score metric (UPSM), the conditional uniform prior score metric (CUPSM), the Dirichlet prior score metric (DPSM), the likelihood-equivalence Bayesian Dirichlet score metric (BDe), and the minimum description length (MDL) [22]. They concluded that the tenth-order DPSM is the best score metric. If the Dirichlet distribution is assumed, then the score metric can be written as [23, 24].

From an empty network with no edge, the greedy algorithm repeats the procedure of adding an edge that maximizes a score gain on the current structure and fixes the new structure as a current one until the structure converges. Though the algorithm can get stuck in the local minimum, it can perform well if the number of variables is relatively small. If the number of variables is large, a global search algorithm such as a genetic algorithm is a more appropriate choice. In this domain, we assume that relevant variables are selected by the expert and the learning procedure is conducted by the greedy algorithm. Figure 2 shows the pseudo algorithm of the greedy search.

3 Case Studies: Three Applications

In this section, we would like to present about three applications of Bayesian network for chance discovery. Each application represents one of the three different levels of chances. Low-level chance is likely to subsymbolic (hard to be understood by humans) because it is based on complex interactions of low-level sensors. In this application, we apply Bayesian network to detect rare system fault before it occurs. Based on probability information, users can be prepared for critical system-down by swapping some components (parts) of applications. In middle-level, something human-understandable but based on data-driven induction concepts is main focus of chances. Detection of relevant objects given occlusions is challenging tasks and proper detection of objects can give service robot opportunity of doing right job or avoiding severe risks.

```
/* n : Number of variables */
/* A[i,j] : Score gain when an edge from jth node to ith node is connected */
/* Score(B) : Score of Bayesian network structure B */
/* Score(B, j→i) : Return a score when B has an edge (j→i) */
/* Find_Max(A) : Return an edge (j→i) that has an maximum A[i,j] */
/* Min : minus infinity */
/* Ancestors(x_i) : A set of nodes that have a path from the node to x_i */
/* Decendants(x_i) : A set of nodes that have a path from x_i to the node */
/* Stop(); If all (i,j), A[i,j]≤0 or A[i,j]=Min then True */
FOR i 1 to n { Pa(x_i) – φ; }
FOR i=1 to n { FOR j=1 to n {
      IF i≠j THEN A[i,j]=Score(B, j→i) – Score(B); }}
WHILE(TRUE){
   (i, j)=Find_Max(A);
   IF A[i,j]>0 THEN  Pa(x_i) = Pa(x_i) ∪ {x_j};
   A[i,j]=Min;
   FOR a=1 to n { FOR b=1 to n {
     IF  x_a ∈ Ancestors(x_j) ∪ {x_j}  &&  x_b ∈ Decendants(x_i) ∪ {x_i}
     THEN A[a,b]–Min; }}
   FOR k=1 to n {IF A [i,k]>Min THEN A[i,k]=Score(B, k→i) – Score(B); }
   IF Stop()==True THEN break;
}
```

Fig. 2. Pseudo code of greedy search for Bayesian network

In this application, we present template-based modeling method of Bayesian network. By reducing the design space of Bayesian network, the model can be easily designed by human expert and machine learning algorithm. Finally, high-level chances are detected based on human-level concepts. It is based on the common sense of humans and chances can be modeled by human as a prior knowledge. Exceptional cases of human knowledge are encoded in the Bayesian networks by the expert.

3.1 Case 1: Low-level

BNs are used to detect future system faults for the decision module that selects appropriate components in component-based middleware. Some information from remote servers through networks (such as availability of specific components, system resource status, and network accessibility) might be uncertain if there are unexpected delays caused by network congestion. Given information from system, the middleware automatically reconfigure

Table 2. Accuracy of the learned Bayesian network on the test data (Time interval = 3 seconds)

	CPU LOAD>8.6	CPU LOAD<8.6	Accuracy
CPU LOAD>8.6	173	11	94.02%
CPU LOAD<8.6	11	953	98.85%
Total	184	964	96.44%

the component-based applications by adding, deleting, and replacing components (building blocks). The probabilistic information about the system's future status can be visualized or utilized by human expert or other decision theory to decide appropriate actions. The Bayesian network provides the probability of future system faults given current system resource and application information.

The basic idea of reconfiguration is as follows. For each functional group, there are a number of redundant components with different properties. In the reconfiguration procedure, the functional graph of the application will not change but each component of the function is replaced with an appropriate component with the same function. The decision of selecting an appropriate one from the functional group is based on the inferred results from the BNs. Evidence is inputted into the BNs with uncertainty and this provides belief about the query nodes with probability. Finally, component-swapping rules are used and their conditional parts contain variables that are inferred from the BNs. Figure 2 summarizes the procedure.

Figure 6 shows the structure of the automatically learned BNs. Data are collected from users for 90 minutes (30 minutes for learning, 60 minutes for test) on linux server. If the CPU load is larger than predefined threshold, it is recognized as system fault (At the threshold, some multimedia player works wrong). Using current CPU resource and application usage information, the BN estimates the probability of CPU overload. The percentage of overload is relatively low and it is estimated before it occurs. Table 3 shows the accuracy of the learned models on test data. It shows 96.44% accuracy. Especially, its accuracy on the positive samples (true) is 94.02%.

3.2 Case 2: Middle-level

In indoor environments, vision-based service robot requires to account for undetected objects that are too small or occluded by others (can be considered as a chance for relevant acvity recognition). The Bayesian network designed to model the object relationship based on activity is called an activity-object Bayesian network. For each activity, related objects are grouped and their relationships are encoded in Bayesian networks which are used to estimate the probability of object's existence given various obstacles (occlusion). In this section, a template-based approach for building Bayesian networks is proposed.

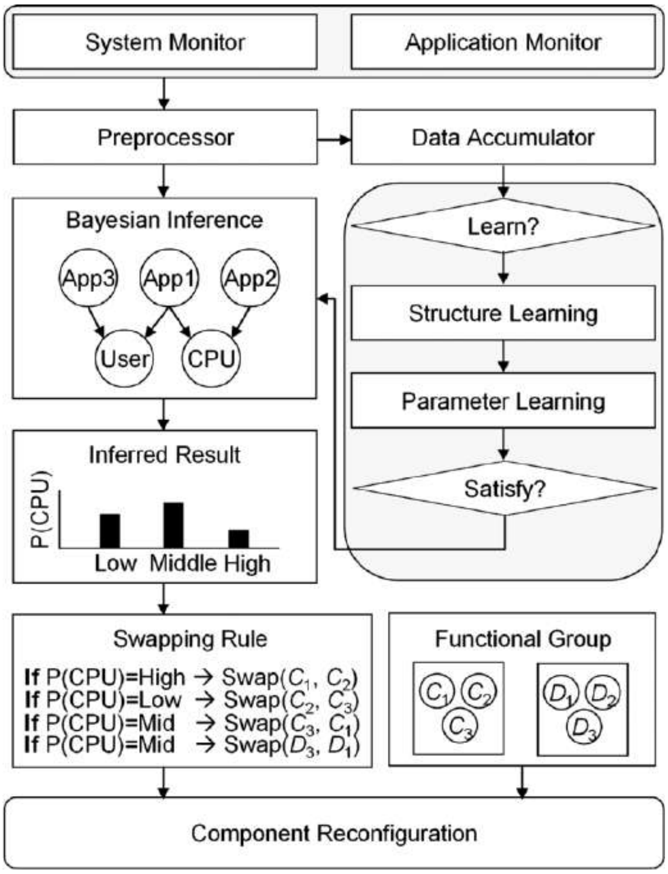

Fig. 3. Component reconfiguration using BNs

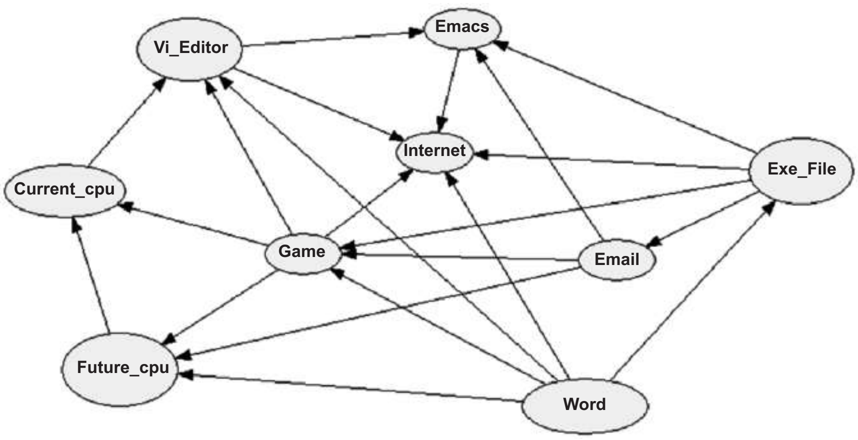

Fig. 4. Bayesian networks learned from data

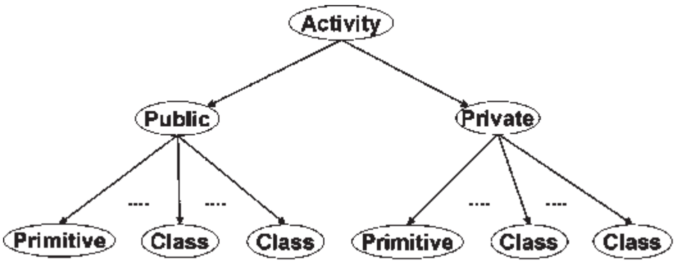

Fig. 5. Basic structure of the activity-object Bayesian network

Classification	Contents
Places	Lecture room, Meeting room, Seminar room, Computer room, Rest room , Prof. office, Admin. office, Guard office, Lab., Stair, Corridor, Elevator, Toilet
Objects	Table, Chair, Round table, Sofa, Cushion, Lectern, Cabinet, Bookcase, Garbage can, Sink, Seat toilet, Wall clock, Air conditioner, Telephone, Computer, Mouse, LCD monitor, Keyboard, Beam Projector, Projection Screen, Audio, Speaker, Microphone, Board, Partition, Curtain, Water bucket, Door, Window, Vending machine, Beverage, Book, Key

Fig. 6. Service environment

The activity-object Bayesian network has a tree structure which is composed of four kinds of basic nodes: an activity node (A), a class node (C), a primitive node (O), and a virtual node (V). The activity nodes are used as root nodes, and they represent the relationship between the objects. Class nodes are used to show more specific relationships between the objects which are known as the building blocks of the Bayesian network. Primitive nodes represent observed or target objects for detection. Virtual nodes are used for adjusting the influence between the objects. We obtain the object relationships by using these kinds of nodes.

Two more nodes are also used as class nodes: public class nodes and private class nodes. Public class nodes are general and can be reused commonly with only slight adjustments in other activity-object Bayesian networks. Private class nodes have specific class nodes related to activity. The object relationship within private nodes is discovered by experts on a case-by-case basis. Public class nodes show weaker relationships to activity, because they are widely used in many cases and include only a small amount of information. The basic structure of the activity-object Bayesian network is shown in Figure 8.

In our experiments, a robot performed services in a university environment. We designed activity-object Bayesian networks which included 15 places and 29 objects (summarized in Figure 9).

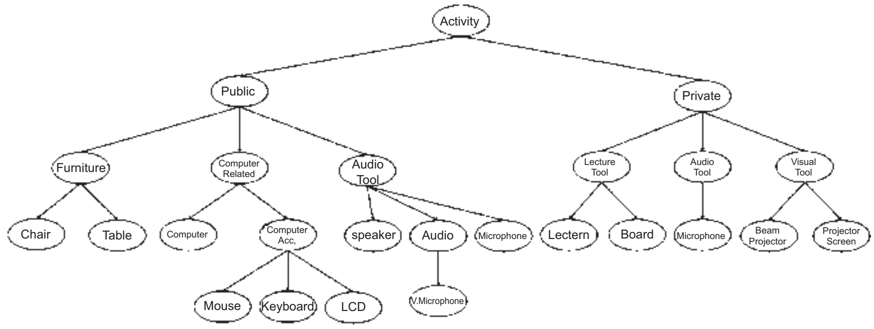

Fig. 7. Presentation activity-object Bayesian network

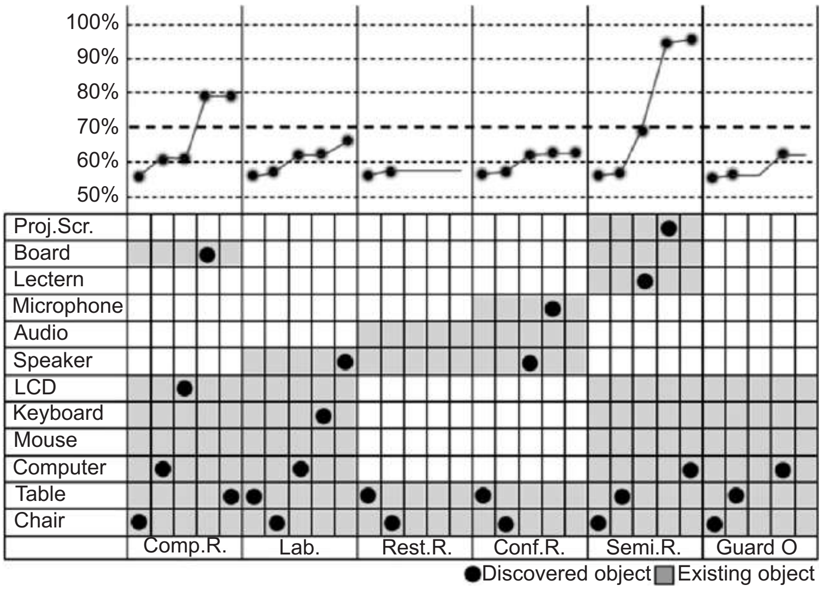

Fig. 8. The changes of probability of the beam-projector

Experiments were carried out to verify the performance of activity-object Bayesian networks in six different places (Computer room, Laboratory, Rest room, Conference room, Seminar room and Guard office). We used two activity-object Bayesian networks: the presentation activity-object Bayesian network was used for finding the beam-projector 11. We assumed that the service robot would move from place to place and randomly detect objects. We recorded the values and hit rates to predict the probability of target objects being present in each place. The target objects refer to the beam-projector.

Figure 14 shows the changes of probability of the beam-projector in the presentation activity-object Bayesian network.

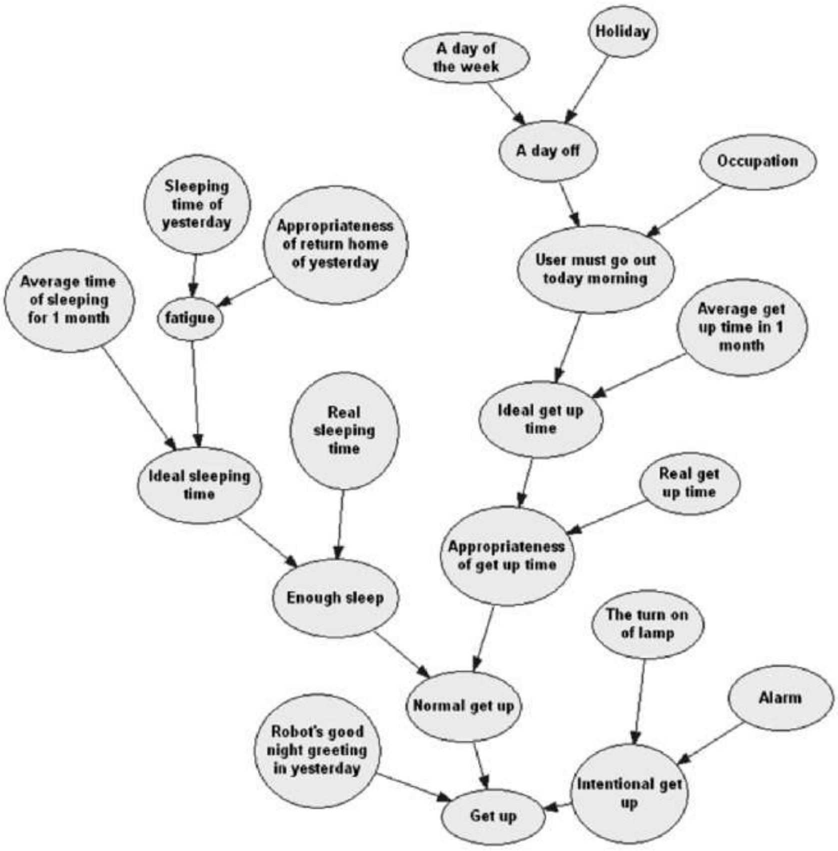

Fig. 9. Morning Bayesian networks

The probabilities of the beam-projector being present in each place were observed under a threshold of 70% until the robot was able to find five objects. The prediction seemed reasonable except in one case. Although the robot predicted that a beam projector existed in both the computer room and the seminar room, in fact, the projector did not exist in the computer room. This denoted that a false-positive error is likely to occur in similar environments that contain many objects related to a beam-projector. Thus, it is important to determine the value of the threshold and the number of times to find objects for each performance.

3.3 Case 3: High-level

Service robot needs to understand common sense of human and exceptional chances that are relevant for human-robot interaction. It is not easy to learn such knowledge from bottom-up manner. We have implemented context-aware system based on uncertain knowledge inference for ubiquitous robot which can access numerous sensors, user profile and calendar information. The robot navigates the inside of home and provides useful services to the user based on the inferred context. For example, they are music recommendation, greeting, and surveillance services. Because the services are very sensitive to the context of the user, it is very important to infer correct context from low-level information.

The robot has many sensors such as humidity, temperature, audio, light, and magnetic sensors. Using RFID tag, the location of the user and objects can be easily determined. Furthermore, the sensor provides the identification of objects (the name of person). If robot recognizes the person using RFID tag, personal information (schedule, name, occupation, income, outcome, relationship with other people, favorites) can be accessible directly from the user profile.

Especially, context-aware system for greeting services is developed using Bayesian networks. The selection of greeting is highly related to the context of the situation. There are four different types of greetings in the morning. Small icons on the top of each situation describe basic information from raw sources such as calendar, time, conversation, light, door, calendar, and temperature. Given some information, Bayesian networks infer the context of each situation. It is not necessarily that all the information is observable and it allows some missing information.

There are 19 different situations for greeting services. We have defined heuristic rules to choose some Bayesian networks. For example, if the user is on the door, Door greeting Bayesian network is selected. In this scenario, the most important situations are morning, night, unexpected and door. The selection of other Bayesian networks is determined based on the inferred results from the major four networks. The average number of nodes and edges for 19 Bayesian networks are 13 and 14, respectively. Because two nodes share one edge, the number of edge is relatively small. Figure 9 shows morning Bayesian network. The robot user the Bayesian networks to guess users current goal. For example, MorningBN is used to guess users getting up. Though user goes out from the bed room, there is possibility that it is not get up. User can get up to go toilet or drink water for a minute. In this case, the robot must provide appropriate greetings. By modeling unusual greetings, the robot can interact naturally with humans. For example, if user returns home very lately at night and there are some friends who visit his house, we can guess that they will drink some alcohol with high probability. If it is very special day such as birthday and event day, the probability will rise up. But if user has very important meeting in the early morning, the probability of drinking alcohol will decrease.

Figure 10 shows the organization of multiple Bayesian networks. Based on the inferred results from the major four Bayesian networks (Morning, Night, Door, Unexpected), other 14 Bayesian networks are selected.

IF robot sees user go out from bed room && time is morning
THEN "Morning" BN
IF robot sees user go to bed room && time is night
THEN "Night" BN
IF user is in the door **THEN** "Door" BN
IF "Get up" is false from "Morning" BN
THEN "Toilet," "Close/Open Window", "Drinking water" BNs
IF "Get up" is true from "Morning" BN
THEN "Reading a book," "Exercise" BNs
IF "Sleeping" is false from "Night" BN
THEN "Studying" BNs
IF "Coming in/out" is false from "Door" BN
THEN "Cleaning," "Cart Away Garbage," "Check mailbox,"
"Going to near store," "Going to car,"
"Check milk or newspaper" BNs

Fig. 10. Rules for selecting Bayesian networks

4 Conclusions

Chance discovery in the uncertain domains will be faced with various challenges such as missing information, unclear definition of chance, and degree of relevance problem. To deal with such challenges naturally, well-defined probabilistic models can be easily used to detect novel chances from the information of sensor, user profile, and user's feedback. Case studies on low-level, middle-level, and high-level domains show that the Bayesian network-based approach might be promising, but there are still a lot of things remained to investigate the relationships between the two fields to exploit the uncertainty reasoning for chance discovery.

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Digital Modulation Classification using Fuzzy Neural Networks

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Summary. Chance discovery is the ability to recognize the presence of a chance in the daily encounter with events. The capacity to realize the chance requires comprehension of the knowledge embedded in the events. This paper introduces a new fuzzy neural network, called MLVQ-FCMAC, for solving the digital modulation classification problem by discovering the underlying relations within the digital modulation classification domain. It is based on the Cerebellar Model Articulation Controller (CMAC) structure, and employs the Modified Learning Vector Quantization (MLVQ) algorithm to partition the input data and derive membership functions. Eight modulation types (ASK2, ASK4, ASK8, FSK2, FSK4, FSK8, PSK2, PSK4 and PSK8) are considered. Six features extracted from the signals are used for classification. Extensive tests have been conducted and compared with two other fuzzy neural networks found in the literature, namely DIC-FCMAC and Falcon-MART. The results show that the MLVQ-FCMAC is able to achieve consistently high classification rates for all modulation types and noise levels. The performance is also independent of the carrier frequency of the signals.

1 Introduction

Communication systems transmit signals in a modulated form in order to match the characteristics of the communication channel. An automatic modulation classifier is a system that automatically recognizes the type of modulation used from the received signal alone [1]. Automatic modulation classification has applications in a number of different areas. They include signal confirmation, interference identification, spectrum monitoring and management, electronic surveillance, and military threat analysis.

Automatic modulation classification techniques found in the literature generally belong either to the decision theoretic or the pattern recognition approach. Decision theoretic techniques such as those described in [2] set boundary thresholds for each feature of signal. The majority rule is then applied to decide which modulation format the signal belongs to. Even though

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over 94% classification accuracies are reportedly achieved, the major disadvantage of the decision theoretic approach is that performance depends on the correct setting of the decision thresholds. The dynamic nature of the signal environment for most communication systems makes the setting of this threshold non-trivial.

The pattern recognition approach typically use artificial neural networks (ANN) as classifiers. Examples of this approach include [2, 3]. The advantage of using ANN is that thresholds need not be predetermined due to ANN's learning ability. However, it is difficult to find an optimal clear cut-off classification boundary because features selected are generally not mutually independent. The need to appreciate the relationships between the input and output vectors in the form of fuzzy semantic concept networks is crucial to the discovery of a chance and the subsequent application of the knowledge to distinguish the new novel cases. Fuzzy set theory can be used to remedy these situations. This allows the forming of internal or mental models of the situations they are dealing with, and rerunning these scenarios in their minds (as memories) to look ahead, anticipate consequences, and seeing, recognizing and matching patterns. The underlying basis of these cognitive faculties is the ability to acquire knowledge and store them for future use, that is, *learning* and *memory.* Neuropsychological studies on human and animal memory have established the existence of multiple brain systems for memory, namely *declarative* (explicit), *procedural* (implicit) and *emotional* memories. Lopatka and Pedzisz [4] incorporated fuzzy logic concepts into modulation classification. They claimed that the classifier works properly for SNR above 5dB. However, with no exact classification rates are reported.

Hence, chance discovery requires the acquisition of novel information, the transformation of such information into a knowledge base to facilitate the identification of a chance phenomenon, and the subsequent definition of a rational response through decision-making by logical reasoning. Developing intelligent systems and computing techniques to meet such complex demands can draw inspiration from the human way of learning and reasoning with information. The flexibility provided by fuzzy sets and the computational efficiency of neural networks for pattern recognition problems makes their combination a good candidate for the task at hand. Fuzzy neural networks (FNN) have been applied to many control and classification problems [5, 6]. So far, the FNN approach to the modulation classification problem has yet to be explored. In this paper, we introduce a new fuzzy neural network called MLVQ-FCMAC for the modulation classification problem. The effectiveness of this network is investigated. Classification results are compared to two existing fuzzy neural networks: the Falcon-MART [7] and DIC-FCMAC [8]. The modulation formats considered include 2, 4 and 8-level amplitude-shift keying (ASK), frequency-shift keying (FSK) and phase-shift keying (PSK). Even though only three modulation types are considered, the classification task is not trivial due to the presence of noise and the similarity of various modulation formats such as FSK and PSK.

The rest of this paper is organized as follows. In Section 2, the architectures of the new MLVQ-FCMAC is described in detail. Falcon-MART and DIC-FCMAC are also briefly reviewed. The six features derived from the sampled signal that are suitable for modulation classification are introduced in Section 3. Classification results and observations when these FNNs are applied to modulation classification are presented in Section 4.

2 Fuzzy Neural Networks Classifiers

Three fuzzy neural networks are applied to the modulation classification task. We shall first describe the new one, MLVQ-FCMAC, in detail. The remaining two existing FNNs are then briefly reviewed.

2.1 MLVQ-FCMAC

The classifier we propose to use is based on the Cerebellar Model Articulation Controller (CMAC) structure. We employ the Modified Learning Vector Quantization (MLVQ) algorithm [9] to partition input data and derive fuzzy membership functions, and implements Takagi-Sugeno-Kang (TSK) fuzzy rule inference. It shall be referred to as *MLVQ-FCMAC*.

Input Quantization and Fuzzy Inference Rule Model

For CMAC networks, it is important to select an appropriate quantization algorithm that truly reflects the nature of distribution of input data to efficiently utilize memory. In a fuzzy neural network, the input space is usually quantized so that fuzzy sets are formed on quantization intervals and hence form the antecedents of IF-THEN fuzzy rules. These fuzzy sets are represented by appropriate membership functions. Several methods for automatically deriving membership functions from input data have been proposed [10, 11, 12] and among them the *Modified Learning Vector Quantization (MLVQ)* algorithm shows its advantages. The fuzzy sets formed by MLVQ, or in other words the antecedents of fuzzy rules, are represented by bell-shaped functions:

$$f(x) = \frac{1}{1 + \left|\frac{x-c}{a}\right|^{2b}} \tag{1}$$

where a, b, c are constants.

Two bell-shaped function examples with different parameters are shown in Fig. 1. Though the bell-shaped membership function requires more computation time than the simple triangular function or trapezoidal function, it can generate smoother approximation.

The consequents of fuzzy rules in MLVQ-FCMAC are represented by crisp values for efficiency in computation. As a result, MLVQ-FCMAC is equivalent

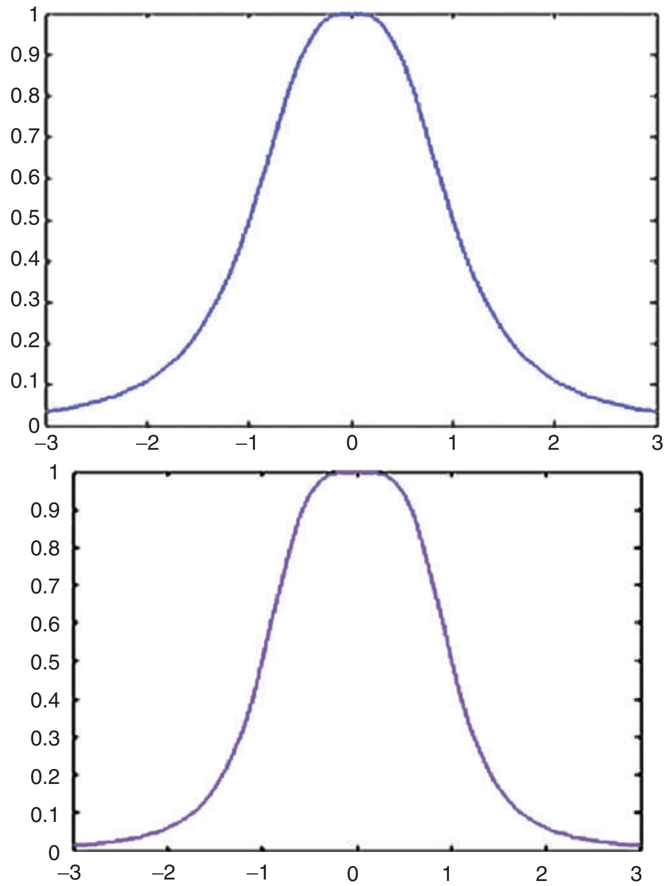

Fig. 1. Bell-shaped functions

to the zero-order *Takagi-Sugeno-Kang (TSK)* inference model [13, 14, 15]. The TSK model consists of rules of the following form:

$$\begin{aligned} R_i : IF\, x_1\, is\, A_{i1}\, AND\, \ldots\, x_r\, is\, A_{ir}\, THEN\, y &= f_i(x_1, x_2, \ldots x_r) \\ &= b_{i0} + b_{i1}x_1 + \cdots + b_{ir}x_r \end{aligned}$$

where f_i is the linear model, and b_{ij} $(j = 0, 1, \ldots, r)$ are real-valued parameters.

The total output of the model is given by

$$y = \frac{\sum_{i=1}^{L} \alpha_i f_i(x_1, x_2, ..., x_r)}{\sum_{i=1}^{L} \alpha_i} = \frac{\sum_{i=1}^{L} \alpha_i (b_{i0} + b_{i1}x_1 + ... + b_{ir}x_r)}{\sum_{i=1}^{L} \alpha_i} \tag{2}$$

where L is the total number of rules, α_i is the degree of input $< x_1, x_2, ..., x_r >$ matching the $i-$th rule, which is typically computed using the "min" operator:

$$\alpha_i = \min\{\mu_{Ai1}(x_1), \mu_{Ai2}(x_2), ..., \mu_{Air}(x_r)\} \tag{3}$$

or the product operator:

$$\alpha_i = \mu_{Ai1}(x_1) \times \mu_{Ai2}(x_2) \times ... \times \mu_{Air}(x_r) \tag{4}$$

where $\mu_{Aij}(j = 0, 1, \ldots r)$ is the membership function of the j-th fuzzy set of i-th rule.

In MLVQ-FCMAC, the matching degree α_i is computed using the min operator. To illustrate how the TSK inference model is used to derive output in MLVQ-FCMAC, Fig. 2 shows a situation where each of the two input dimensions is partitioned into four fuzzy sets, resulting 16 rules being created. For the input $< x', y' >$, four fuzzy IF-THEN rules are activated due to two fuzzy sets being involved in each dimension. The four cells corresponding to the activated fuzzy rules are shaded in Fig. 2, all contributing to the final output. In MLVQ-FCMAC, the real-valued parameters a_1, a_2, b_1 *and* $b_2$are set to zero, and hence the activated four rules are expressed as:

$$R_{12} : IF\ x\ is\ X_1\ and\ y\ is\ Y_2\ THEN\ z = c_{12}$$

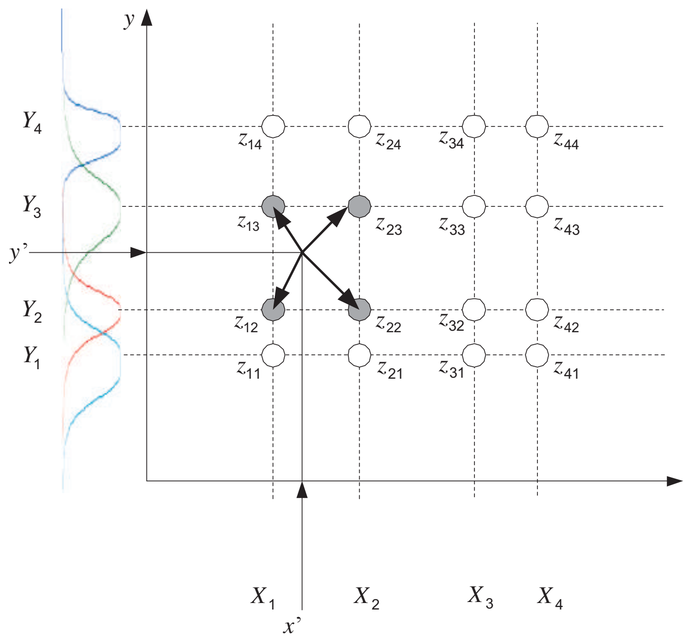

Fig. 2. Illustration of TSK model in a 2-input MLVQ-FCMAC.

$$R_{13} : IF\ x\ is\ X_1\ and\ y\ is\ Y_3\ THEN\ z = c_{13}$$

$$R_{22} : IF\ x\ is\ X_2\ and\ y\ is\ Y_2\ THEN\ z = c_{22}$$

$$R_{23} : IF\ x\ is\ X_2\ and\ y\ is\ Y_3\ THEN\ z = c_{23}$$

Hence, the final output is given by

$$y = \frac{\alpha_{12}c_{12} + \alpha_{13}c_{13} + \alpha_{22}c_{22} + \alpha_{23}c_{23}}{\alpha_{12} + \alpha_{13} + \alpha_{22} + \alpha_{23}}$$

where $\alpha_{ij} = \min\{\mu_{Xi}(x'), \mu_{Yj}(y')\}$ is the degree of $< x', y' >$ matching rule R_{ij}.

The Training Algorithm

The proposed MLVQ-FCMAC employs a two-phase training algorithm. During the first phase of training, the MLVQ algorithm is used to partition training data into clusters and determine the cluster centers for the derivation of fuzzy membership functions. Fuzzy sets are constructed based discovered clusters, and are represented by asymmetric bell-shaped functions for greater accuracy. An asymmetric bell-shaped function simply combines two bell-shaped functions with same c and b but different a. The parameter c is the cluster centre found by MLVQ for its corresponding fuzzy set, and b is a constant defined prior to training and can be adjusted according to specific applications. Parameter a deserves a bit more elaboration. In fact, one fuzzy set is represented by the left half and another one by the right half of the bell-shaped function. Hence a separate a is used to "describe" the width of the flat portion of each of the two bell shapes. The value of a for the left bell-shaped function is determined by the standard deviation of data belonging to the left half of the cluster, and same argument applies to the right bell-shaped function.

In the second phase of training, IF-THEN fuzzy rules are activated by inputs and output is computed as described in the previous section. Contents of activated cells are updated accordingly, to minimizing the error of the actual output from the desired output. The overall training process proceeds as follows:

1. Initialize parameters for MLVQ-FCMAC.
2. Data is fed into MLVQ-FCMAC, and MLVQ algorithm is invoked to determine the cluster centers in all input dimensions simultaneously.
3. Parameter a of each bell-shaped membership function for the fuzzy sets discovered by MLVQ in Step 2 is determined by calculating the standard deviation of data distribution belonging to its corresponding cluster.
4. Initialize the internal structure according to the partition of input space.
5. MLVQ-FCMAC receives input data, determines rules to be activated in the same way as illustrated in Fig. 2, and calculates output from activated cells.

6. Adjust the consequents of activated cells according to the error as follows:

$$z_i^{new} = z_i^{old} + \beta\alpha_i e \tag{5}$$

$$e = y_{desired} - y_{actual} \tag{6}$$

   where β is the learning parameter, α_i is the degree of matching with the respective IF-THEN fuzzy rule, and e is the difference between the desired output and the actual output.
7. Repeat steps 5 to 6 for all inputs.

Benchmark Results

The proposed MLVQ-FCMAC is benchmarked with the popular Fisher's Iris classification problem. The result shows that MLVQ-FCMAC can achieve average classification rate of 97.33% with standard deviation of 0.52% for memory-recall testing, and classification rate of 96% with standard deviation of 1.89% for generalization testing. Hence, MLVQ-FCMAC is capable of solving classification problem.

2.2 DIC-FCMAC

DIC-FCMAC, first proposed by Tung and Quek [8], is a fuzzy neural network based on the *Cerebellar Model Articulation Controller* (CMAC) which is capable of performing localized generalization with very fast learning [16]. In DIC-FCMAC, fuzzy logic is incorporated into a new CMAC architecture, transforming CMAC into a white box whereby fuzzy rules can be generated to interpret the operation of the network. DIC-FCMAC has been extensively benchmarked against existing architectures on different problems, and the results reveal that it is competent in solving classification problems.

2.3 Falcon-MART

Falcon-MART is fuzzy neural network that can be used as a fuzzy controller. It has also been applied to forgery detection, pattern recognition and data analysis [7]. It is a modification of the of the original Falcon-ART architecture proposed by Lin and Lin [17]. Falcon-ART is an on-line structure/parameter learning mechanism that combines the back-propagation algorithm for parameter learning and the fuzzy adaptive resonance theory (fuzzy ART) for structure learning. Falcon-ART is a highly autonomous system. Initially there are no membership functions or fuzzy set rules. They are created and begin to grow as learning proceeds, in an unsupervised way. Falcon-ART applies the fuzzy ART algorithm to partition the input-output spaces into fuzzy hyper-boxes and to determine fuzzy logic rules by connecting the proper input-output hyper-boxes. The back-propagation algorithm is then used to tune the membership functions. Falcon-MART is a variant of Falcon-ART which was proposed by Quek and Tung to overcome several of the later one's shortcomings.

3 Feature Set for Classification

The M-ary ASK, FSK and PSK signal samples are obtained from the general expression

$$y_m = A_m \cos(2\pi f_m i/f_s + \theta_m) \tag{7}$$

for $m = 0, 1, ..., M-1$, and $1 \leq i \leq N_s$, where N_s is the number of samples. Parameters A_m, f_m and θ_m used for simulating the concerned digitally modulated signals are selected as presented in Table 1.

The choice of signal features greatly affects the performance of the classifier. As a general solution to the digital modulation classification problem is desired, the chosen features must be relatively invariant to the communication environment. For example, they should not vary undesirably within a wide range of noise levels. In other words, they should characterize the respective modulation type or group of modulation types, rather than any particular instance of the signal.

Six features are used, three of which are primarily based on the instantaneous amplitude, and the other four are based on the instantaneous frequency. There are several ways to compute the instantaneous frequency of a signal [18, 19]. In this paper it is computed using the autoregressive spectral analysis method [20].

The first feature, σ_{peak}, is the standard deviation of a sequence that is obtained from the normalized instantaneous amplitude sequence $\{A_i\}$ where the samples are considered as the waveform peaks and troughs.

$$\sigma_{peak} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(|peak_i| - |\overline{peak}|\right)^2} \tag{8}$$

where

$$\overline{peak} = \frac{1}{n}\sum_{i=1}^{n} peak_i \tag{9}$$

$$A_i = \frac{(y_i - \overline{y})}{y_{\max} - y_{\min}} \tag{10}$$

Table 1. Selection of Digitally Modulated Signals Parameters. (f_c is the carrier frequency and f_d is the frequency deviation.)

Modulation type	M	A_m	f_m(kHz)	θ_m
MASK	2	$0.5 + 0.5m$	f_c	$\pi/4$
	4	$0.25 + 0.25m$	f_c	$\pi/4$
MFSK	2	1	$f_c + (2m-1)f_d$	$\pi/4$
	4	1	$f_c + (m-2)f_d$ if $m < 2$ $f_c + (m-1)f_d$ if $m \geq 2$	$\pi/4$
MPSK	2	1	f_c	$\pi/4 + m\pi$
	4	1	f_c	$\pi/4 + m\pi/2$

$$y_{\max} = \max(y_i) \tag{11}$$

$$y_{\min} = \min(y_i) \tag{12}$$

Note that σ_{peak} is independent of the energy of the signal. MPSK and MFSK signals have constant energy levels, thus they should have a relatively small σ_{peak} compared with MASK signals. ASK2 has two energy levels and ASK4 has four. Thus ASK2 should have a larger σ_{peak} than ASK4, provided that they have the same maximum energy.

The second feature, σ_{nf}, is the normalized standard deviation of instantaneous frequency:

$$\frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(|f_i| - \overline{f})^2}}{\overline{f}} \tag{13}$$

σ_{nf} is normalized by the mean of the instantaneous frequency so that it is independent of the actual carrier frequency of the signal. Since MASK and MPSK signals have a constant carrier frequency and no frequency deviation, they should have a relatively small σ_f compared with MFSK signals. FSK2 have two different frequencies and FSK4 signals have four. Thus FSK4 would have a larger σ_f than FSK2, provided that their frequency deviation is the same or close enough.

The idea of the third feature, denoted $\sigma_{diff-psd_f}$, originates from the fact that the histogram of the instantaneous frequency sequence of single-tone signals (MASK and MPSK) theoretically has only one peak, while that of MFSK signals has M peaks. It is defined by

$$\sigma_{diff\_psd_f} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(|diff\_psd_f(i)| - \overline{diff\_psd_f}\right)^2} \tag{14}$$

Here psd_f is the magnitude of the fast Fourier Transform (FFT) of the histogram of the instantaneous frequency, and

$$diff\_psd_f = diff\,(psd_f(1:m/2)) \tag{15}$$

where m is the number of bins in the histogram, $diff()$ is the difference function being used to approximate the first derivative, and $(1:m/2)$ refers to the first $m/2$ elements of a sequence.

The fourth feature, $\sigma_{diff-psd_{peak}}$, is defined by

$$\sigma_{diff\_psd_{peak}} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(|diff\_psd_{peak}(i)| - \overline{diff\_psd_{peak}}\right)^2} \tag{16}$$

where psd_{peak} is the magnitude of the FFT of the histogram of the absolute peak values and

$$diff\_psd_{peak} = diff\,(psd_{peak}(1:m/2)) \tag{17}$$

The rationale for this feature is that the histogram of the derived amplitude peak sequence of a signal has an equal number of peaks to the number of energy levels of the signal. In other words, MPSK and MFSK signals theoretically have only one peak in their histogram as they each have a constant energy level, while MASK signals have M peaks.

The fifth feature, denoted δ_{nf}, is the normalized first derivative of the instantaneous frequency, defined by

$$\delta_{nf} = \frac{\overline{\delta}_f}{\overline{f}} \tag{18}$$

where

$$\delta_f = |diff(f)| \tag{19}$$

δ_{nf} is normalized against the mean of instantaneous frequency and hence it is independent of the carrier frequency. Since single-tone signals have a constant frequency, the mean of the instantaneous frequency difference should be small after normalization. Due to the way the instantaneous frequency is computed, the frequency spikes in MPSK signals due to symbol transitions would have been eliminated significantly. Hence δ_{nf} would still be small for MPSK signals. On the other hand, their instantaneous frequency difference would have a relatively large mean, proportional to the deviation ratio after normalization.

The last feature is the kurtosis of the sequence, $\{peak_i\}$ of the signal, denoted $kurt_{peak}$, and defined by

$$kurt_{peak} = \frac{E\left[(p(t) - \overline{p})^4\right]}{\sigma_p^4} \tag{20}$$

where E is the expectation operator, $p = |peak_i|$, and

$$\sigma_p = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(|p_i| - \overline{|p|})^2} \tag{21}$$

Kurtosis is a measure of how outlier-prone the distribution is. Distributions that are more outlier-prone than the normal distribution have kurtosis greater than 3. Experiments show that MPSK and MFSK signals have larger $kurt_{peak}$ than MASK signals.

4 Modulation Classification Results

4.1 Simulated Signal Generation

Modulated signal samples are generated using (7) based on the parameters given in Table 1. Initial experiments show that the six features are most robust when the sampling rate is five times higher than the carrier frequency. Thus tests were only conducted with data simulated at this sampling ratio. This does not defeat the goal of a generic classifier, as the sampling rate can be easily adjusted to achieve the desired sampling ratio.

One important parameter of a signal is the symbol rate, which is usually related to the carrier frequency. The ratio of carrier frequency f_c to symbol rate f_s is set to within a reasonable range – between 2.5 and 10. The carrier frequency used in simulated signals is 100kHz and hence data is collected at seven symbol rates: 10kHz, 15kHz, 20kHz, 25kHz, 30kHz, 35kHz, and 40kHz. The deviation frequency of MFSK signals is set to 1/10 of the carrier frequency, i.e. 10kHz. Knowing that carrier frequency can be estimated with error rate bound within 5% using autoregressive spectrum analysis, data is collected at the target f_s/f_c ratio (5, in this case) as well as $f_s/[(1 \pm 5\%)f_c]$ (i.e. 4.7 and 5.3), simulating the frequency estimation error that may be encountered in practice.

White Gaussian noise is added into the simulated signal to make data practical. Ten sets of data are generated each at SNR = 10dB, 15dB, 20dB, 25dB, and 30dB. Each set consists of 2520 samples in total, with an equal number of samples from each class, and each class having equal number of samples at each symbol rate. A separate set of data at all SNRs and all symbol rates is used to train the MLVQ-FCMAC.

4.2 Results Using DIC-FCMAC

Classification results using DIC-FCMAC is presented in Table 2. The performance is generally good for SNR of 15dB or above. PSK is the most difficult modulation format to classify correctly. The confusion matrix in Table 3 shows that most mis-classifications are intra-modulation types for binary and 4-ary signals. That means PSK4 is misclassified as PSK2, etc.

Performance for FSK8 and PSK8 signals are the worst. The results show that success rate for FSK8 signals is less than 45% at all SNR, while DIC-FCMAC is able to classify ASK8 and PSK8 signals with success rate of over

Table 2. Overall Classification Rate using DIC-FCMAC (%)

Modulation Type	SNR (dB)				
	10	15	20	25	30
ASK2	77.45	98.05	95.48	100	99.81
ASK4	72.62	95.83	97.45	99.81	99.71
ASK8	100	100	100	100	100
FSK2	74.81	89.86	88.21	90.98	92.81
FSK4	97.6	98.88	98.81	99.1	99.24
FSK8	42.86	35.24	25.95	26.67	27.86
PSK2	21.17	71.14	87.43	87.45	87.31
PSK4	92.02	77.07	66.43	78.52	72.17
PSK8	99.29	100	100	100	100

Table 3. Confusion matrix for binary and 4-ary signals using DIC-FCMAC at SNR=10dB.

	ASK	FSK	PSK
ASK	99.90	0.10	0
FSK	0	97.6	2.39
PSK	0	0.55	99.45

Table 4. Confusion matrix for 8-ary signals using DIC-FCMAC.

	ASK	FSK	PSK
ASK	100	0	0
FSK	32.62	42.86	24.52
PSK	0	0.71	99.29

Table 5. Falcon-MART Configuration.

Parameter	Value
Learning constant in BackPropagation algorithm (η)	0.005
In-vigilance Parameter in the Fuzzy MART algorithm (ρ_{in})	0.8
Out-vigilance Parameter in the Fuzzy MART algorithm (ρ_{out})	0.8
Termination criterion (ε)	0.00005
Sensitivity Parameter of the Trapezoidal Membership Function (γ)	2.0
Maximum number of training iterations	100

99%. The confusion matrix for these signals shown in Table 4 reveals that there are substantial misclassifications for FSK8 signals as ASK and PSK ones.

4.3 Results using Falcon-MART

The parameter of Falcon-MART that we have used is shown in Table 5.

Some of the results are quite surprising, sharply different from those of DIC-FCMAC. It seems to perform better for modulation types with higher number of levels. In fact, it was almost perfect for ASK8, FSK8 and PSK8 at all SNR. However, its performance was poor for ASK2 (at 15dB and below), FSK4 and PSK4. To find out how Falcon-MART generalizes for each modulation family, confusion matrices formed by grouping modulation types into their corresponding family are drawn and shown in Table 7. It can be seen that Falcon-MART generalizes for all three families very well, with success rate of over 98% at SNR of 10dB.

4.4 Results Using MLVQ-FCMAC

The average classification rates for each modulation type at various noise levels are summarized in Table 8. The classification rates for MASK signals

Table 6. Overall Classification Rate using Falcon-MART (%).

Modulation Type	SNR (dB)				
	10	15	20	25	30
ASK2	2.38	6.98	96.33	99.36	99.81
ASK4	99.48	99.57	99.98	99.95	99.93
ASK8	100	100	100	100	100
FSK2	99.95	99.88	99.48	99.43	99.05
FSK4	0.12	0.74	69.81	75	75.21
FSK8	100	100	100	100	100
PSK2	87.69	92.98	94.07	97.76	97.57
PSK4	0	0.26	10.17	12.29	12.14
PSK8	98.81	99.76	100	100	99.05

Table 7. Confusion matrix grouped by modulation families using Falcon-MART.

10dB	ASK	FSK	PSK
ASK	99.81	0	0.19
FSK	0	99.93	0.071
PSK	0	1.75	98.37

Table 8. Classification rates for each modulation type at different SNRs (%).

Modulation Type	SNR (dB)				
	10	15	20	25	30
ASK2	95.19	98.33	91.21	99.71	99.52
ASK4	91.90	97.24	94.21	98.48	98.62
ASK8	98.33	100	100	100	100
FSK2	88.98	95.52	97.02	97.57	96.60
FSK4	98.48	99.12	99.50	99.26	98.86
FSK8	93.57	98.81	98.57	97.86	97.14
PSK2	79.43	85.38	89.62	91.79	93.67
PSK4	67.50	80.90	83.57	90.48	87.88
PSK8	98.09	99.29	99.76	99.29	97.14

are greater than 91% for MASK signals, and greater than 98% for SNR at and above 25dB. MLVQ-FCMAC achieves classification rate $\geq 95\%$ for MFSK signals at SNR $\geq$ 15dB. It can be observed that classification rate for MPSK signals monotonically increases with increasing SNR, except for PSK4 signal at SNR = 30dB. It can also be seen that MLVQ-FCMAC performs better as SNR increases and reaches its optimal performance at SNR = 25dB. Thus the performance of MLVQ-FCMAC is better than that provided by DIC-FCMAC and Falcon-MART.

Table 9. Confusion matrix for modulation families at SNR = 10dB (%).

Modulation family	Predicted modulation family		
	ASK	FSK	PSK
ASK	99.61	0.38	0.01
FSK	0.87	97.77	1.36
PSK	0.02	1.62	98.4

Table 10. Classification rate for signals with different f_c (%).

f_c (Hz)	SNR (dB)		
	10	15	20
10K	87.62	92.02	92.58
100K	85.91	92.32	92.29
1M	86.67	92.38	93.17

The confusion matrix for SNR = 10dB is shown in Table 9. It shows very few inter-modulation type confusion (FSK wrongly classified as ASK or PSK etc).

We further investigated the effect of the carrier frequency to the classification results. To determine if the extracted features are truly independent of carrier frequency, MLVQ-FCMAC is trained with data generated with carrier frequencies of 10kHz and 1MHz while the test data are at a carrier frequency of 100kHz as before. The overall classification rates averaged over all modulation types are shown in Table 10. The consistent results confirm that the performance of MLVQ-FCMAC is essentially independent of the carrier frequency. It also shows that the six features are also independent of the carrier frequency of the signal.

5 Conclusions and Future Work

In this paper, we introduced a fuzzy neural network, MLVQ-FCMAC, for solving the digital modulation classification problem as a neuro-modelling tool to the chance discovery of phenomena in classes in the frequency classification of signals. The learning of fuzzy semantic relationships between the input and output vectors prior to the subsequent use of the knowledge structure to handle newly recognized cases. The performance of this FNN is compared to Falcon-MART and DIC-FCMAC. Results show that MLVQ-FCMAC is better able to classify ASK, FSK and PSK signals from binary to 8-ary at signal-to-noise ratios of 10dB or higher. We also showed that the performance of the network and the feature set is independent of the carrier frequency of the signals.

Further efforts to improve performance, especially for MPSK signals, is necessary and mainly lies in extracting new robust features that incorporate phase information and remove the dependence on the deviation ratio. Finally, it is worth pointing out that though MLVQ-FCMAC is proposed for solving classification problems, it has the potential to work for problems in other areas, such as function approximation, time series prediction, which remains to be explored in future.

The Centre for Computational Intelligence, C^2I, undertakes the investigation and development of advanced hybrid neural fuzzy architectures such as [21, 22, 23, 9], and [24] for the modeling of *complex*, *dynamic* and *non-linear* systems. These techniques have been successfully applied to numerous novel applications such as automated driving [25] signature forgery detection [26], gear control for *continuous variable transmission* (CVT) in car system [7] and fingerprint verification [27].

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Chance Discovery using Complementary Learning Fuzzy Neural Network

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Summary. Chance discovery is an emerging field of study that gains increasing interest and found its application in wide variety of real world problems. Detecting chance is profiting because one can make use of the good opportunities or avoid the disastrous risks. However, chance detection and management is non-trivial. Consequently, chance discovery tools are needed to assist human or notifying them the existence of chances. *Complementary Learning Fuzzy Neural Network* (CLFNN) is a biological, neuropsychological-inspired fuzzy neural network that functionally models the human recognition decision making. A segregation of positive and negative knowledge is observed in human brain. In recognition decision making, the lateral activation of positive and inhibition of negative knowledge leads to accurate and effective response to the stimuli. CLFNN models this concept and hence, offers superior recognition performance. Furthermore, CLFNN is capable of autonomously constructs these positive and negative rulebase, which is critical for chance discovery. On top of that, the segregation of positive and negative knowledge facilitates the chance discovery process. The CLFNN possesses inference that is highly akin to the human decision making and abduction analogical reasoning processes. This enhances tractability and assists the discovery of new chances. A diabetes diagnosis problem to demonstrate the feasibility of CLFNN in stimulating chance awareness is conducted. CLFNN is shown to be an attractive tool for chance discovery.

1 Introduction

Chance, either opportunity (positive chance) or risk (negative chance), is an event that plays a significant role in human decision making [1]. A chance possesses these natures [2]: (1) uncertainty; (2) accident; (3) probability. Therefore, a decision involving chance takes these into account, where choices are made under uncertainty to determine which future scenarios (sequence of events) or actions is more probable; accident implies an opportunity or risk led by uncertainty. Chances, by definition, are rare, novel, or some scenarios that one feels empathy with [2]. The rarer the situation is, the stronger impact the chances tend to have [3]. Moreover, chance is unpredictable. Taxonomy of chance has been proposed in [4].

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Consequently, chance discovery is important and beneficial when noticed opportunity is exploited and risk discovered is avoided [5]. Note that chance discovery is the search of chance, and not by chance, albeit a chance can be discovered by chance. Thus, chance discovery refers to the learning and explanation of a chance event [6]. Since it is a discovery of chance, its definition includes the element of connecting previously unnoticed/unconnected components of the domain, a similarity to the term "creativity". Moreover, as chance discovery is a human cognition process [7], it is closely linked to several human cognitive processes and behaviors. For example, *abductive reasoning* [8, 9], *anticipation* [10], *concept articulation* [11], *emergence* [12], affects [13], *inductive reasoning* [14] and *serendipity* [15]. There are criteria proposed to evaluate the chance discovered [3]: (1) *Proposability* – the capability of proposing a certain decision/action based on the understanding of the chance; (2) *Unnoticability* – the difficulty involved in noticing the significance of the chance; (3) *Growability* – the rate of growth of the number of people who accept the proposal based on the chance .

Formally, chance discovery involves a 5-tuple: $< X, A, R, B, Y >$, where X is the set of events, A is the set of patterns, described by X, R is the relation that links A to B, which is a series/patterns of future *scenarios*/outcomes, and Y is the outcome or scenario suggested by B. In chance discovery, one focused on the X or A that trigger an unusual/novel pattern of B, which is not described by the already known R, and this leads to an unexpected Y. The X and A in this case can be novel or normal events. One can also generate a sets of hypothetical scenarios of B and Y, by changing the X or A. This process is known as *scenario creation* [16], which is useful in discovering potential chance events. Hence, the goal of chance discovery is to identify the set of X or A (i.e. chance) that will create new B or Y, or a specific set of X or A (or seemed-to-be outlier [17]) that will invoke unusual/unexpected B or Y [18]. Chance discovery also aims at the identification of cognitive factors involved in the processes, as well as development of tools to support these processes [16]. Viewing from the other perspective, chance discovery is the decision making or search of action that one takes to realize his/her implicit and explicit desires [19]. Thus, chance discovery is not merely the exploration of chances, but also the management of these chances. Besides, note that the chance discovery is a spiral cyclic process; it goes from acquisition of chance, analysis of chance, decision making, evaluation of outcome, and goes back to the first step [1].

However, discovery of chance is difficult, either in a domain with overwhelming information or a domain with little information. Real world problems of chance discovery are highly complex, and demand inference under uncertain and dynamic situations; which very often, pushes the limit of human cognition [7]. Chances are, only relevant to an individual's interest, and their effects cannot be known ahead of time [19]: only time can tell whether a discovered chance is really a chance. Hence, chance discovery tools are needed in order to aid the chance discovery process. Chance discovery tool/approach seeks to identify chances and to improve the awareness of chances. A chance goes unnoticed is useless; unless one is aware and act on the chance, the benefits will not be gained [20]. These tools can discover new and previous chances that are hidden under the data. Awareness of such previous chances, or knowledge of chances (a kind of *tacit knowledge* [21]), is important to guide the discovery of future chances, and create new understanding of the domain [22]. Some examples of chance discovery tools/approaches are: *Keygraph* [1], *textdrop* [1], *Bayesian inference* [7], *scenario analysis* [6], *double helix model* [23], *chance storification* [21], and *Genetic programming* [4]. These tools can be classified into *knowledge-learn approach* that uses statistics analysis to identify chances, and *knowledge-intensive approach* that utilizes learned knowledge [24]. The proposed *Complementary Learning Fuzzy Neural Network* (CLFNN) belongs to the later one. Since chance discovery requires extensive knowledge of current situations (circumstances) to develop the awareness of chances [25], CLFNN which is capable of automatically constructing declarative knowledge from data, provides an attractive alternative for chance discovery and management. CLFNN explicitly generates and employs positive and negative rules, which facilitates users in the comparison of outcomes, as well as the detection of novel, outliers, or anomaly pattern. By contrasting and exploiting the relation between the positive and the negative, one can model the dynamic of the data in a more precise way. In addition, this aids the analysis as well as extraction of the nature of positive and negative information; thus, ease the unusual pattern discovery. Hence, the CLFNN is proposed as a chance discovery and management tool.

The field of chance discovery has been a hot research topic since its debut. Chance discovery is shown to be a useful study that may bring benefit to various areas of study or real-world problems. This includes business, medicine, financial, education, and so on. Fig. 1 summarizes some of the successful applications of chance discovery, indicating the fruitfulness of the chance discovery study. Note that this list is non exhaustive.

The organization of this paper is as follows: Section 2 outlines the biological inspirations that formed the proposed CLFNN, and discusses the characteristic of this class of fuzzy neural network. The relationship between the abductive analogical reasoning critical to chance discovery and CLFNN is shown in Section 3. Aside from that, the mapping of a human-like inference process to CLFNN is presented in the same section as well. An experimental study of CLFNN as a chance discovery tool using a diabetes diagnosis task is listed in Section 4. Section 6 concludes this current work and discusses some possible future work.

2 Complementary Learning Fuzzy Neural Network

Complementary learning refers to positive and negative learning, where positive is the class that the system seeks to recognize, and negative is the class

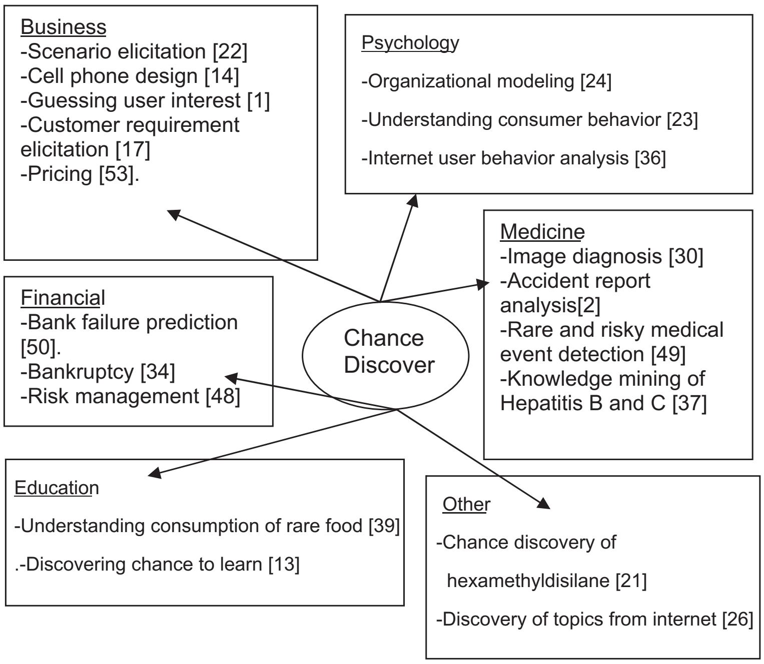
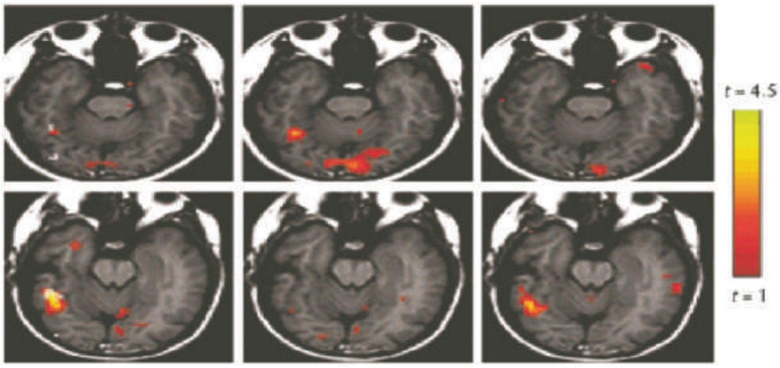


Fig. 1. Applications of chance discovery.

that the system seeks to classify out. This form of positive and negative learning generates a segregated positive and negative knowledge bases. Subsequently, the inference is done based on the contrast between the responses of positive and negative knowledge bases. If the decision made is positive, then a lateral inhibition will take place, where the decision or firing strength of the negative knowledge base is suppressed. This is a functional model of how human makes a recognition decision: neuro-psychology and neurocognitive science studies show that human's knowledge acquisition is based on the positive and the negative learning, a role played by the *hippocampus* structure in human brain [23]. In human pattern recognition, human registers different brain areas for different object recognitions. For example, human faces are registered at the *lateral fusiform gyrus* [26, 27], houses are registered at the *medial fusiform gyrus* [26], whereas cars are registered at areas around the *occipital lobe* [27], and so on. Hence, the segregation of knowledge for different object recognition enables the correct response to be selected and to be acted out. Whenever a human face (positive) is shown, only *lateral fusiform gyrus* area is activated, and at the same time, the other irrelevant brain areas (areas registered for other objects, i.e. negative) will be inhibited, leading to a successful and accurate recognition (Fig. 2). Modeling this mechanism is advantageous, particularly in recognition problems.

Bird Expert



Car Expert

Fig. 2. Slices of fusiform gyrus of car and bird expert in face, car, and bird recognition. The rectangular boxes show the activated areas of brain for different recognition task (Adapted from [27], with permission from *Nature Neuroscience*.

Fuzzy neural network implementing complementary learning is called CLFNN. Formally, a CLFNN is a 5-tuple as well: $< X, A, R, B, Y >$, where $X = X^+ \cup X^-$, = a set of positive (patterns/samples associated with positive outcome) and negative (samples associated with negative outcome) events/stimuli respectively; $A = A^+ \cup A^-$, are the corresponding fuzzy membership functions which describe the patterns of X^+ and X^-. In CLFNN, trapezoidal membership function is used due to its lesser computational requirement. Likewise, B consists of the fuzzy membership functions representing the patterns of outcome Y, and is similarly divided into positive and negative groups, B^+ and B^-, corresponding to positive Y^+ and negative Y^- outcomes, respectively. Finally, $R = R^+ \cup R^-$ are the rules which associate the patterns of events to the patterns of outcomes based on the training data, i.e. $R : A \to B$. Hence, whenever X^+ is presented, R^+ will be activated, and concurrently, R^- will be inhibited, leading to positive outcome Y^+, and vice versa, as depicted in Equations 1 and 2:

$$\mu_{R^+}(X) = \begin{cases} 1, & \text{if } X \in X^+ \\ 0, & \text{Otherwise} \end{cases} \tag{1}$$

$$\mu_{R^-}(X) = \begin{cases} 1, & \text{if } X \in X^- \\ 0, & \text{Otherwise} \end{cases} \tag{2}$$

where $\mu_R(\cdot)$ is the membership function of the rule. This setting facilitates the detection of outliers, anomaly patterns, or unusual events. Because CLFNN infers on the basis of the comparison of positive and negative, an outliers or unusual event is relatively easier to be identified. For instance, a X or A close to the X^+ or A^+ but is associated with Y^- (a surprise [14]), or a Y^+ that has

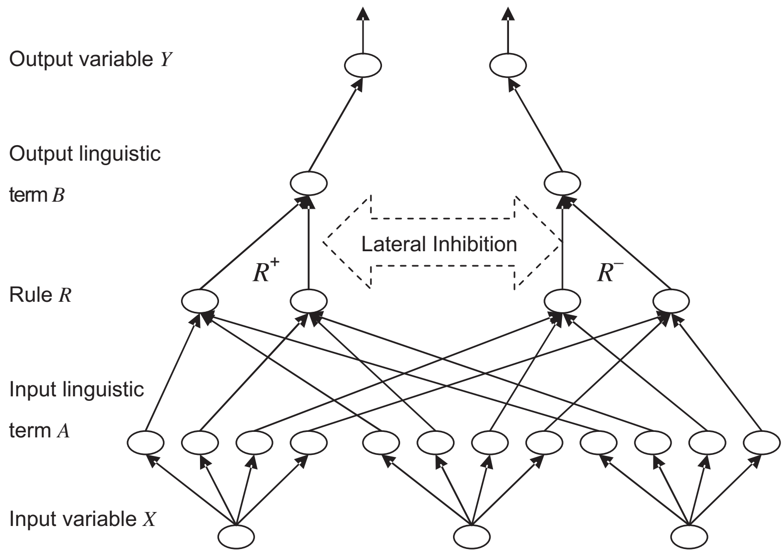


Fig. 3. Complementary learning fuzzy neural network. Apart from Layers 1 and 5, all other layers are constructed autonomously by the complementary learning algorithm. The system determines itself the number of nodes needed to model the training data. Positive and negative rules are generated separately. For details, see [30].

a very different form of X or A, etc. Hence, CLFNN possesses the capacity to provide support for the chance discovery processes.

The knowledge representation of CLFNN is in the form of IF-THEN rules. For example, IF X is A THEN Y is B. The "X is A" clause is the antecedent, and "Y is B" is the consequent. These rules are data-driven, which the CLFNN generates autonomously from the training data. CLFNN is a 5-layer network, where each layer corresponds to the elements of the IF-THEN rules (Fig. 3).

3 Approximate Analogical Reasoning Scheme

Chance discovery can be viewed as a form of *abduction reasoning*. Abduction reasoning refers to the inference or formation of certain facts or hypotheses, in order to explain novel situation, phenomenon or observations [9]. Abduction creates a set of plausible hypotheses, and then selects the one that best describes current observations. According to this view, a chance is a missing or unknown hypothesis that explains anomalous, unusual events or observations [28, 29]. The process of searching hypotheses, evaluation, and selection to puzzling phenomenon is closely related to the activities of finding and producing chance [9]. Conventional abduction theory assumes perfect knowledge base, which does not cater to the chance discovery process that is inherently uncertain. It has to be extended to incorporate the chance discovery process, i.e. the generation of unknown hypotheses. Hence, abduction under incomplete knowledge base, termed as *abductive analogical reasoning* [28] is brought into picture. In abductive analogical reasoning, it no longer explains, but predicts based on a set of observations. Moreover, abductive analogical reasoning forms an imperfect or fuzzy hypothesis based on known facts or experiences, rather than an exact mapping of observations and known rules, and subsequently infers decision based on the imperfect hypothesis. Thus, abductive analogical reasoning is important and necessary for chance discovery [29], particularly in cases where no sufficient data or knowledge is available.

CLFNN supports such abductive analogical reasoning that is necessary for chance discovery. CLFNN is mapped with a fuzzy inference scheme known as *Approximate Analogical Reasoning Scheme* (AARS) [31], which closely resembles the human decision making and the abductive analogical reasoning processes (for details, see [32, 33]). The inference steps of CLFNN are as follows:

Given a vector of input $x = (x_1, ..., x_i, ..., x_I)$, where i is the index of the input dimension.

Step 1: Input fuzzification - fuzzified the input using singleton or non-singleton fuzzifier, as delineated in Equation 3.

$$\mu_{\tilde{X}_i}(x_i) = \begin{cases} x_i, & \text{singleton fuzzifier} \\ \tilde{x}_i, & \text{non-singleton fuzzifier} \end{cases} \tag{3}$$

Step 2: Antecedent matching – compared the fuzzified inputs and the antecedents of each rule. The similarity can be computed using various distance measures. In CLFNN, since each antecedent is a trapezoidal membership function, the similarity is computed using the trapezoidal membership function. CLFNN performs antecedent matching using Equation 4, where k is the index of rule, A is the antecedent of the rule, and * is the t-norm operation of fuzzy sets.

$$Similarity_{ik} = \mu_{\tilde{X}_i}(x_i) * \mu_{A_{ik}}(x_i) \tag{4}$$

Step 3: Rule fulfillment – computes the overall similarity of each rule, as defined in Equation 5.

$$Similarity_k = \frac{1}{I} \sum_{1}^{I} Similarity_{ik} \tag{5}$$

Step 4: Consequent derivation – derives the conclusion based on the degree of matching between the stored knowledge and the observed inputs, as given in Equation 6.

$$\mu_{B_k}(y) = \bigcup_{x \in X} [\mu_X(x) * \mu_{R_k : A_k \to B_k}(x, y)] \tag{6}$$

where y is the desired outcome,

$$\mu_X(x) = \mu_{X_1 \times \ldots \times X_I}(x) = \mu_{X_1}(x_1) * \cdots * \mu_{X_I}(x_I)$$

and

$$\mu_{R_k:A_k \to B_k}(x, y) = \mu_{A_{1k}}(x_1) * \cdots * \mu_{A_{Ik}}(x_I) * \mu_{B_k}(y)$$

Step 5: Output defuzzification – reduces the fuzzy set to crisp output, as shown in Equation 7.

$$y = (u + v)/2 \tag{7}$$

where (u, v) is the lower and upper limits of the trapezoidal membership function $\mu_B(\cdot)$.

As shown, the deduction process of CLFNN is closely akin to the human decision making, and the abduction reasoning process. In particular, in Step 4, the derivation of conclusion is a fuzzy process, where the inference is based on a prediction/explanation or approximation of the previous learned knowledge. This corresponds well with what abduction analogical reasoning postulated: the prediction based on previous knowledge and imperfect hypothesis. Furthermore, the inference process is human-like, which enhances the tractability and eases human understanding of the system, as shown in Table 1. Users can assess and validate the system performance in his/her familiar terms.

On top of that, the use of AARS allows the application of linguistic *hedges* such as 'very', 'rather', etc, to the membership functions in antecedent and consequent of the fuzzy rules, by means of its modification functions, as displayed in Fig. 4. This expansion and reduction form of AARS modification functions correspond to the effect of applying 'more or less' and 'very' to the membership function respectively. The former gives a more relax condition for rule activation, whereas the later gives a more constraint condition for rule activation. In other words, the expansion form captures more uncertainties,

Table 1. Inference processes of CLFNN and human beings.

Steps	**CLFNN**	**Human**
1	Present a sample or events.	Observe a set of events.
2	Compute the similarity of current events with previous experience and knowledge.	Assess the similarity of current observation based on past experience and knowledge.
3	Select the rule with the maximum overall similarity. Activate positive knowledge, and inhibit negative knowledge.	Chose the experience and knowledge that best described current circumstances. The judgment involves activation of related brain areas and inhibition of irrelevant brain areas.
4	Derive conclusion based on the similarity.	Derived based on how similar the current situation compared to last experience and knowledge.
5	Output the decision.	Act out the decision.

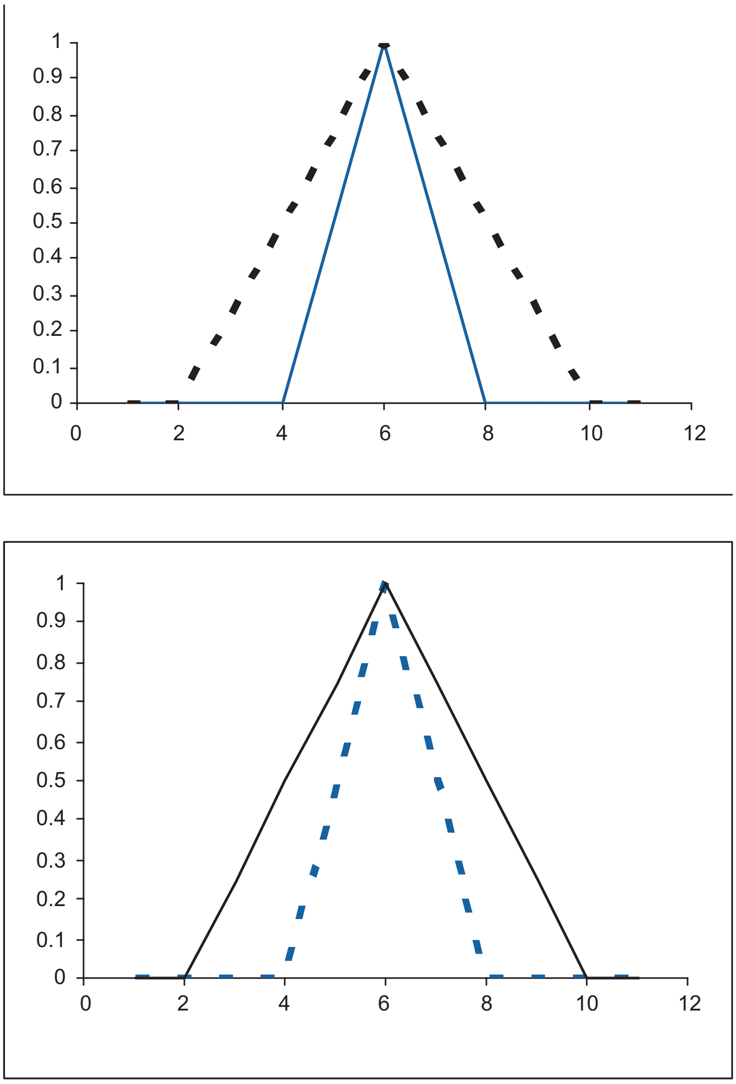


Fig. 4. Expansion and reduction form of AARS modification functions.

and implies there are high dissimilarity between the observed input and the stored knowledge. The reduction form implies a close matching between the observed inputs and stored knowledge. Using these linguistic modifications to the antecedents and consequents of the rules, new scenarios can be generated and analyzed for discovering potential chance events.

4 CLFNN as Chance Discovery Tool

In order to demonstrate the feasibility of CLFNN as a chance discovery tool, an experiment is conducted: diabetes diagnosis problem. The Pima Indian diabetes dataset obtained from the UCI repository [34] is used to assay the system as a chance discovery tool. This dataset was originally donated by Vincent Sigillito, Applied Physics Laboratory, Johns Hopkins University, and was constructed by constrained selection from a larger database held by the National Institute of Diabetes and Digestive and Kidney Diseases. A total of 786 patients are represented in this dataset who are females at least 21 years old of Pima Indian heritage living near Phoenix, Arizona, USA. The attribute details are given below:

1. Number of pregnancy
2. Plasma glucose concentration in an oral glucose tolerance test
3. Diastolic blood pressure (mm/Hg)
4. Triceps skin fold thickness (mm)
5. 2-hour serum insulin (mU/ml)
6. Body mass index (kg/m^2)
7. Diabetes pedigree function
8. Age (years)

Ten-fold cross validation is used to assay the system, i.e., the dataset is divided into ten subsets. Nine are used for training and one for testing, and repeat for ten times such that each subset is used for testing exactly once. The task is to predict whether a patient would test positive for diabetes according to World Health Organization criteria (i.e. if the patients' 2 hour post–load plasma glucose is at least 200 mg/dl.) given a number of physiological measurements and medical test results. The dataset is rather difficult to classify. The so-called "class" value is really a binarized form of another attribute that is itself highly indicative of certain types of diabetes but does not have a one–to–one correspondence with the medical condition of being diabetic.

A CLFNN named FALCON-AART (FA) [33] are used to illustrate the feasibility of applying it as chance discovery tool. FA is benchmarked against some common data mining tools [35]: *k-Nearest Neighbor* (kNN), *Support Vector Machine* (SVM), *Radial Basis Function* (RBF), *Naive Bayesian*, C4.5, and *Multilayer Perceptron* (MLP). The averaged results are presented in Table 2: "recall" is the diagnosis accuracy on the training set, whereas "predict" is the diagnosis accuracy on the testing set. Sensitivity and specificity are defined in Equations 8 and 9 respectively. In this case, positive means cases with diabetes.

$$\text{Sensitivity} = \frac{\text{Number of positive samples correctly diagnosed}}{\text{Total number of positive samples}} \tag{8}$$

$$\text{Specificity} = \frac{\text{Number of negative samples correctly diagnosed}}{\text{Total number of negative samples}} \tag{9}$$

Table 2. Averaged results for the Pima Indian diabetes diagnosis.

Method	Recall (%)	Sensitivity (%)	Specificity (%)	Predict (%)
kNN	100.0	80.0	56.0	71.61
SVM	79.16	87.6	57.5	77.08
RBF	77.08	87.6	54.5	76.04
Naive Bayesian	78.9	86.4	61.2	77.6
C4.5	89.58	80.4	61.2	73.7
MLP	87.23	85.6	67.9	79.43
CLFNN (FA)	83.79	80.0	81.48	80.52

One have to know what is usual before one can tell what is unusual. In other words, accurate knowledge of a domain is important to detect chances in that domain. Hence, the ability of the method in modeling the data accurately is of great importance. A more accurate model can discover more chances [10]. Therefore, in order to detect chances, superior performance in diagnosis is required. As shown in Table 2, CLFNN exhibits a competitive performance compared against the other data mining methods, in spite of the fact that the dataset is difficult to classify.

Apart from superior performance, using CLFNN has advantages of autonomy and interpretability compared to some approaches such as SVM, Bayesian inferences, etc. The CLFNN is capable of constructing its declarative knowledge autonomously, and generate a set of positive and negative fuzzy IF-THEN rules that capture the dynamics of the data. These rules are intuitive and are paramount in giving insights to the problem domains. The rulebase building can be viewed as the process of transforming tacit knowledge (hidden traits or experiences gained from the data) to its explicit form (IF-THEN rules that are interpretable, applicable by user), which is crucial for chance discovery [9]. These rules are external representation of knowledge, which can aid researchers in identifying aspects, making further inferences, and guide the decision making process by limiting possible outcomes that leads to an increase in chance discoverability. Moreover, this explicit knowledge representation can be shared and analyzed by domain expert, alleviating the *capture bottleneck problem* (the lack of incentives for users to invest time for knowledge and resources sharing [36]). As knowledge is context dependent [13, 15, 37] the employment of fuzzy rules that allows the application of linguistic terms, enables the preservation of information in its original context. This equips CLFNN with the knowledge (and chance) management capability. On the other hand, if the training data consists of extreme or unusual cases, they will be described by exception rules autonomously generated from the data. Such exception rules are useful to make one aware of exception facts (chance), and could play a pivotal role in risk management and avoidance in real world applications [28]. Table 3 shows the example of the rules generated by the CLFNN system.

The rules are simple and can be readily understood by users. These rules are useful to understand the problem domain and can be used to verify certain medical conjectures. For example, (the *italic* antecedents) obesity is a risk factor for diabetes, plasma glucose concentration is an important indicator of diabetic. From these rules, one can expect the pattern to be observed from a diabetes patient to have high plasma glucose concentration, high body mass index, and so on. If a case of diabetes has low plasma glucose concentration, low body mass index, then this case is potentially a chance. Whether it is an opportunity or risk, is dependent on the user. The usage of positive and negative rules, facilitates the detection of rare/unusual events and hence, potential chances. For instance, lets say a diagnostic system only generated two rules as presented in Table 3 (in real situation, a lot more positive and negative rules will be generated, otherwise, the performance of the system will be unacceptably poor; this rare or unusual event in training data will be captured by exceptional rule autonomously generated by the system). If a sample has characteristics such as high plasma glucose concentration (which is between "very high" and "medium"), body mass index is high, diabetes pedigree function is medium, etc. Such input will trigger very similar responses from the positive and negative knowledgebase. This type of sample/event is thus an unusual one and is probably a chance. This event is rare because the system do not construct rules that can describe this event (fuzzy rules are constructed based on frequently encountered examples). Hence, the complementary learning provides a setting that aids the chance discovery process.

The use of linguistic terms such as medium, high, low, etc, allows encapsulations of unnecessary details from the users. These linguistic terms capture uncertainties underlying the data, and are characterized by the fuzzy set/membership function of the system. For example, the linguistic terms describing plasma glucose concentration of each rule presented in Table 3 are shown in Fig. 5.

The inference process is closely akin to the human reasoning and decision making process. It is also similar to that of abductive analogical reasoning, which plays a pivotal role in chance discovery. This characteristic is beneficial because an inference process that is human-like eases the user in understanding the system operation. As a result, CLFNN has an improved tractability. An illustration of CLFNN inference process is given as follows:

Step 1: Present a positive input:

$$\mathbf{x} = [8, 188, 78, 0, 0, 47.9, 0.137, 43], y = [1]$$

Step 2: Since this sample is not exactly represented by the knowledge base, compute on the basis of imperfect knowledge to approximate the input (abduction analogical reasoning). Determine the membership degree based on the

Table 3. Example of complementary rules.

Positive Rule	**IF** Number of times pregnant is medium **AND** *Plasma glucose concentration in an oral glucose tolerance test is very high* **AND** Diastolic blood pressure is medium **AND** Triceps skin fold thickness is very low **AND** 2-hour serum insulin is very low **AND** *Body mass index is very high* **AND** Diabetes pedigree function is rather low **AND** Age is middle **THEN** Diabetic
Negative Rule	**IF** Number of times pregnant is very few **AND** Plasma glucose concentration in an oral glucose tolerance test is medium **AND** Diastolic blood pressure is rather low **AND** Triceps skin fold thickness is rather high **AND** 2-hour serum insulin is very low **AND** Body mass index is medium **AND** Diabetes pedigree function is rather high **AND** Age is rather young **THEN** Normal.

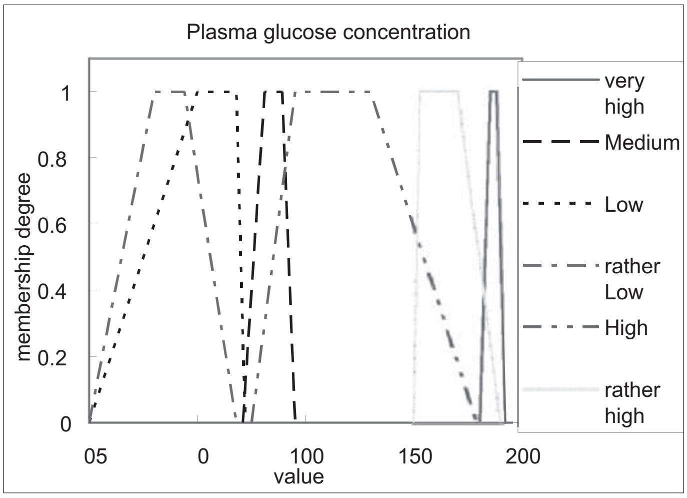


Fig. 5. Linguistic terms of the plasma glucose concentration. Linguistic terms "medium" and "very" high" are generated by the negative and positive rules shown in Table 3 respectively. Other linguistic terms are generated by other rules, but were not shown in this work. The reason being is to reduce the complexity of the illustration.

knowledge stored. For this example, the antecedents of positive and negative rules are:

$$\mathbf{u}^{+} = [8, 185, 78, 0, 0, 47, 0.137, 42]$$
$$\mathbf{v}^{+} = [8, 188, 78, 0, 0, 47, 0.137]$$

$$\mathbf{u}^{-} = [1.004, 85, 66, 29, 0, 26.6, 0.351, 30]$$

$$\mathbf{v}^{-} = [1.007, 85, 66, 29, 0, 26.6, 0.351, 33]$$

Compute the membership degree for each dimension

$$\mu_{A^{+}}(x) = [1, 1, 1, 1, 1, 1, 1, 1]$$

$$\mu_{A^{-}}(x) = [0, 0, 0, 0, 1, 0, 0, 0]$$

Step 3: Select the best rule based on the overall similarity.

$$\mu_{R^{+}}(x) = \tfrac{1}{8}(1 + 1 + 1 + 1 + 1 + 1 + 1 + 1) = 1$$
$$\mu_{R^{-}}(x) = \tfrac{1}{8}(0 + 0 + 0 + 0 + 1 + 0 + 0 + 0) = 0.125$$

Thus, the positive rule is fired, and the negative rule is inhibited.
Step 4: Derives the conclusion base on the consequent linked by the positive rule, based on the similarity measure of the rule (partial knowledge).

$$(u, v) = (0.99, 1.01);\ \text{Positive rule linked to this consequent}$$

Step 5: Carries out defuzzification and output the conclusion.

$$y = \frac{0.99 + 1.01}{2} \times 1 = 1$$

The prediction is "diabetes". Inference process is completed.

The adoption of AARS not only gives CLFNN an inference process that is akin to abductive reasoning, but also the enablement of CLFNN to support the *exploration* and *manipulation* methodologies [24] in chance discovery. Exploration refers to a systematic way of identifying the problem, whereas the manipulation methodology analyzes the relation between modified situation and stored knowledge. AARS allows the modification to the fuzzy set that defines the linguistic term, and thus allows subsequent assay of the system performance under hypothetical scenarios. By modifying different linguistic terms, and different combinations of modifications, a set of hypothetical scenarios can be generated and then analyzed. The analysis of these scenarios may offer the discovery of new chances. For example, to see what if the plasma concentration is "more or less high" instead of "very high", an expansion modification function is applied to the fuzzy set describing the "very high" linguistic term of the positive rule in Table 3. One possible expansion modification function [31] is defined in Equation 10.

$$\mu(x) = \min\left[1, \frac{\mu(x)}{\text{similarity}}\right] \tag{10}$$

If the performance of the rule with expansion form is significantly decreased, then it suggests that it is very unlikely that the diabetic case will have a "more or less high" plasma glucose concentration (other attributes value being constant). If such a case exists, then it will be a chance event. On the other hand, if the performance of the rule increases, it suggests "more or less high" plasma glucose concentration is more frequently observed in diabetes case than "very high". This analysis of hypothetical scenarios provides a better understanding of the domain, and offers also the identification of scenarios that leads to opportunity or risk, i.e. chance.

5 Conclusion

Chance discovery is useful in the identification of potential opportunity to be seized and risk to be avoided. CLFNN is a neuropsychological-inspired fuzzy neural network that can be used as chance discovery adjunct. CLFNN has the capacity of autonomous positive and negative rules construction that accurately model the dynamics of the data. These positive and negative rules are useful in gaining insights of the problem domains, as well as facilitating the detection of rare/unusual patterns, and chance. The inference process of CLFNN (AARS) is closely analogous to the human inference process, and is similar to the abduction analogical process. The incorporation of this AARS inference process improves the tractability of the system and enhances the users' understanding towards the system operation. An experiment conducted on a diabetes diagnosis task shows that CLFNN offers superior knowledge solicitation skill, which is critical for chance discovery. All together, they demonstrate that CLFNN is a competent tool for chance discovery. Unfortunately, CLFNN possesses no ability to show the causal relation between input sequences, which is important to chance discovery in some problem domain. One possible solution is to use a window of size n, to include the input sequences from time t to $t - n$ as the inputs to the CLFNN. However, this approach has two limitations: (1) high computational load. For the case of Pima Indian diabetes diagnosis problem, $n \times 8$ inputs is needed; (2) there is no systematic way of determining the optimal window size. One alternative is to employ the concepts postulated in *spatiotemporal connectionist networks* [38]. In addition, although CLFNN is able to detect potential chance events, no guarantee can be given whether the detected events are chances or noises. The decision lies on the shoulder of human still, to check whether the events are truly an opportunity or risk. Very often, only time can tell whether an identified rare event is noise, outlier, error, or is truly a chance [39]. In the future, with the availability of data, the CLFNN can be used to learn the correct response based on the chance detected, that is providing decision support to the chance management. Alternatively, an ensemble of CLFNNs can be built: one to detect chance, and one to predict, based on the chance detected, whether it is an opportunity or risk, or noise. All in all, CLFNN is an attractive alternative for chance discovery.

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Modeling Influence Diffusion in Human Society

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1 Diffusing Influence in Human Society

In human society, communication is the most important means for exchanging information by which people can establish reliable relationships with others. Such kind of network is called as “social network” or “human netowork”, and over the network people exchange ideas or opinions about various topics they are interested in. Through communication, the thoughts of people are externalized and understood each other by knowing the identity, similarity, heterogeneity, and difference between thoughts they have in mind. In this sense, communication is an essential tool of Chance Discovery because it supports noticing new ideas bridging various thoughts, as in the double herix process of Chance Discovery [8].

Communication as Chance Discovery is not restricted in face-to-face communication. Dramatic development of networking environment provides us new kind of communication tools such as E-mail, BBS, chat etc. As the online communication tools have been pervading in our daily lives, people have come to use the tools for not only talking about daily topics such as fashion or gossip but also discussing about specific and complicated matters such as business or research meeting. In online communication, people usually send or receive messages typed on keyboard, and the messages are stored in computers or computer servers as contrasted to the ones in face-to-face communication. Once communication is stored, the communication data can be analyzed by a computer. The processability of communication covers our weak point that human beings are good at processing qualitative data but not good at quantitative data.

In this chapter, the IDM, an algorithm for analyzing communiaction data, is introduced to show the process of Chance Discovery from point of communication data analysis. The basic strategy of the IDM is very simple. The IDM focuses on the propagating terms from people to people to capture the coherent context of communication. Based on the propagated terms, the IDM

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extracts chances represented as terms, messages, participants, or human networks all of which would triggering new ideas. The process of the IDM is said, in other words, "word-of-mouth" phenomenon where interested topics are circulated. That is, the IDM measure influence as the amount of propagation, and the terms, messages, or human relationships extracted by the IDM are the ones contributing to the diffusion of influence in communication.

2 The IDM

The IDM (Influence Diffusion Model) is originally an algorithm of measuring influential values of each message, sender, and term from messages with post-reply relationships [5]. Here let me introduce the up-to-date algorithm of the IDM [6, 7].

In the IDM, the influence between a pair of senders is defined as the number of terms propagating human-to-human via messages. Here, let a message chain be a series of messages connected by post-reply relationships, and the influence of a message x on a message y (x precedes y) in the same message chain be $i_{x \to y}$. Then, define $i_{x \to y}$ as

$$i_{x \to y} = |w_x \cap \cdots \cap w_y|, \tag{1}$$

where w_x and w_y are the set of terms in x and y respectively, and $|w_x \cap \cdots \cap w_y|$ is the number of terms propagating from x to y via other messages. If x and y are not in the same message chain, $i_{x \to y}$ is defined as 0 because the terms in x and y are used in a different context and there is no relationships between them [1].

Based on the influence between messages, the influence of a sender p on a sender q is measured as the total influence of p's messages on the messages of others through q's messages replying to p's messages. Let the set of p's messages be α, the set of q's messages replying to any of α be β, and the message chains starting from a message z be ξ_z. The influence from p onto q, $j_{p \to q}$, is then defined as

$$j_{p \to q} = \sum_{x \in \alpha} \sum_{z \in \beta} \sum_{y \in \xi_z} i_{x \to y}. \tag{2}$$

The influence of p on q is regarded as q's contribution toward the spread of p's messages.

[1] Sometimes the terms in different message chains seem to have some relationships with each other. To cope with this case, the IDM software has an option that sets temporal post-reply relationships to the messages with some similarities regardless of message chains, but the option didn't used here because of the accuracy of temporal relationships.

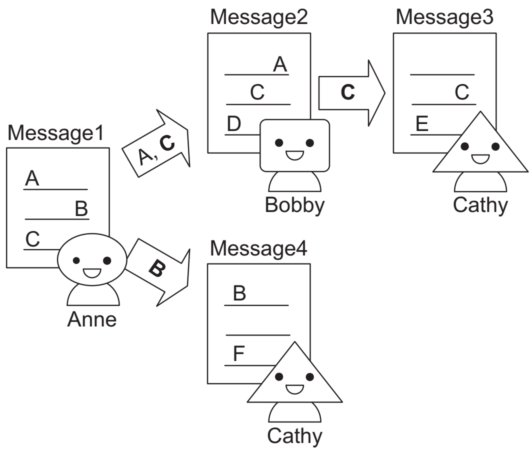

Fig. 1. A message chain of four messages sent by three individuals.

The influence of each sender is also measurable using $j_{p \to q}$. Let the influence of p to others be $I_p^{<1>}$, the influence of others to p be $I_p^{<2>}$, and the set of all staffs except p be γ. Then, $I_p^{<1>}$ and $I_p^{<2>}$ are defined as

$$I_p^{<1>} = \sum_{q \in \gamma} j_{p \to q} \tag{3}$$

$$I_p^{<2>} = \sum_{q \in \gamma} j_{q \to p}. \tag{4}$$

As an example of measuring influence, let us use a simple message chain in Figure 1 where `Message2` and `Message4` are posted as replies to `Message1` and `Message3` is posted as a reply to `Message2`.

Here, the influence between a pair of senders is measured as follows.

- The influence of Anne on Bobby is 3 (i.e., $j_{Anne \to Bobby} = 3$), because two terms (`A` and `C`) were propagating from Anne to Bobby, and one term (`C`) was propagating from Anne to Cathy via Bobby.
- The influence of Anne on Cathy is 1 (i.e., $j_{Anne \to Cathy} = 1$), because one term (`B`) was propagating from Anne to Cathy.
- The influence of Bobby on Cathy is 1 (i.e., $j_{Bobby \to Cathy} = 1$), because one term (`C`) was propagating from Bobby to Cathy.
- The influence of Bobby on Anne and of Cathy on Anne is 0 (i.e., $j_{Bobby \to Anne} = 0$ and $j_{Cathy \to Anne} = 0$), because no term was propagating to Anne from either Bobby or Cathy.

From the influence above, the influential value ($I_p^{<1>}$) and influenced value ($I_p^{<2>}$) of each staff is measured as follows.

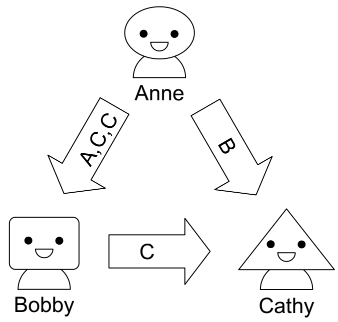

Fig. 2. An influential human network extracted from the message chain in Figure 1.

$$I^{<1>}_{Anne} = j_{Anne \to Bobby} + j_{Anne \to Cathy} = 3 + 1 = 4 \quad (5)$$

$$I^{<2>}_{Anne} = j_{Bobby \to Anne} + j_{Cathy \to Anne} = 0 + 0 = 0 \quad (6)$$

$$I^{<1>}_{Bobby} = j_{Bobby \to Anne} + j_{Bonny \to Cathy} = 0 + 1 = 1 \quad (7)$$

$$I^{<2>}_{Bobby} = j_{Anne \to Bobby} + j_{Cathy \to Bobby} = 3 + 0 = 3 \quad (8)$$

$$I^{<1>}_{Cathy} = j_{Cathy \to Anne} + j_{Cathy \to Bobby} = 0 + 0 = 0 \quad (9)$$

$$I^{<2>}_{Cathy} = j_{Anne \to Cathy} + j_{Bobby \to Cathy} = 1 + 1 = 2 \quad (10)$$

Note that the influence of Anne on Cathy is ignored even though one term (`C`) was propagated from Anne to Cathy via Bobby. Instead, the indirect influence of Anne on Cathy via Bobby is considered as the contribution of Bobby, and add it to the influence of Anne on Bobby.

By mapping the propagating terms between senders, an influential human network can be obtained as in Figure 2, where the number of outgoing terms corresponds to the influential values ($I_p^{<1>}$) and the number of incoming terms corresponds to the influenced values ($I_p^{<2>}$). From the figure, the influential relationships between them are visually understood.

3 Understanding Leadership Behaiors

After NPO (NonProfit Organization) law was established in December 1998 in Japan, specified nonprofit activities have been promoted by the Japanese government, and as a result, more NPOs have been established than before. According to the government web site, the number of authorized NPOs is increasing as follows: 1,000 NPOs in Nov. 1999, 5,000 NPOs in Oct. 2001, 10,000 NPOs in Feb. 2003, 18,000 NPOs in September 2004[2].

[2] http://www.npo-homepage.go.jp/data/pref.html (In Japanese)

The boom reflects the growing needs of people to take part in social activities. Staffs in an NPO are engaged in social activity apart from administration and commercial business. However, it also causes the difficulty of managing NPOs. In more detail, the difficulty comes from the mission of an NPO, voluntarism of staffs, and the scale of organization:

- The primary mission of an NPO is the public benefits, not the profitability. Changing or correcting the mission is justified in profit-driven organization if more profit is promising, whereas not in an NPO.
- The commitment of people to an NPO depends on their voluntarism, not on their obligation. Therefore, a leader can't force staffs to engage in a task against their wills.
- As the number of staffs increases, sharing mission becomes a challenge and weakens staffs' voluntarism.

Much research on NPOs showed that the reliable relationships between staffs were crucial properties in an organization for making the most of human and knowledge capital [3, 2, 12]. Leadership behaviors are also considered to play an important role in making the atmosphere or culture of an organization [10] and creating knowledge from staffs' experiences [4]. In the ongoing project regarding NPOs [9], the aspects of capital, scale of operation, human resources, partnerships with governments and organizations have been illuminated. Yet the relationships between staffs are not investigated enough although it is quite relevant to share missions and motivating voluntarism.

In this chapter, leadership behaviors in "dot-jp" [3], an NPO in Japan, are to be understood by integrating questionnaire survey with influential human networks extracted by the IDM (Influence Diffusion Model) [5, 6, 7]. The results of questionnaire survey are obtained from 97 staffs working in dot-jp to understand the reliability toward leaders from the other staffs. Then, influential human networks from the archives of E-mail used in dot-jp are extracted to understand the influential relationships between leaders and the other staffs over E-mail. Integrating the results of questionnaire survey and influential human networks shows reliable leadership behaviors.

4 Overview of dot-jp

Dot-jp organizes seminars and intern programs giving university students the opportunity to participate in political activities with diet members. Through the intern program, students learn how diet members engage in political activities in their field.

The period of dot-jp's activity continues six months as a unit, and about half of staffs are renewed when new period starts. At the beginning of each period, staffs have to advertise dot-jp's activity to university students to gather

[3] http://www.dot-jp.or.jp/

them to seminars. Also, staffs have to contact with each of diet members, explain about the activity of dot-jp, and ask him/her to take student(s) in as an intern program. Through the seminars being held several times, staffs fix up intern programs to each student who is interested in the political activity of a diet member. Then, intern programs start and students experience political activities as assistants of diet members.

The headquarters of dot-jp is in Osaka, and seven branch offices are distributed all over Japan according to the areas (Branch-A, Branch-B, Branch-C, Branch-D, Branch-E, Branch-F, and Branch-G[4]). Each branch office is organized by nine to twenty one staffs, and three of them are appointed one of the managers below.

- **Area manager:** The person who has responsible for managing all staffs. Area manager is the substantial leader in the branch office.
- **Seminar manager:** The person who has responsible for gathering students to seminars.
- **Intern Manager:** The person who has responsible for contacting with diet members for intern programs.

Most staffs in dot-jp are also university students, and having face-to-face meeting is difficult because of their distant residences and classes at the university. For these reasons, staffs mainly use E-mail as a tool to exchange information, plan and arrange events, argue and agree on matters. On-line communication over E-mail realizes a virtual office, and works as the complement of a real office.

More important things are that the second author of this paper knows much about the management of dot-jp because he had experienced area manager and currently he is in charge of marketing affairs as a marketing director in dot-jp. In addition, this project has cooperated fully with dot-jp. Therefore, in-depth research composed of questionnaire survey, having face-to-face interviews, and extracting influential human networks from the archives of E-mail will be carried out.

5 Questionnaire Survey

Understanding staffs' degree of satisfaction in an organization can be a key to discover specific problems related to the fault of human resources management [1]. In this project, questionnaires were sent to all the staffs (104 staffs) working in dot-jp to understand staffs' degree of satisfaction, especially about their managers and their belonging branch offices. Then, by comparing the result of questionnaire survey received from 97 staffs (correction rate was 93%) with the achievement rate of activity explained later, the factors that lead the activity of dot-jp into success will be discussed.

[4] Instead of real branch names, pseudo branch names are used to keep the secrecy.

5.1 Questionnaires

To investigate staffs' degree of satisfaction to their branch offices, area managers, seminar managers, and intern managers, questionnaires were sent to 104 staffs working in seven branch offices on March 2005, the last month of the 14th period.

The questions in the questionnaire are as follows:

Q1. Please rate the degree of satisfaction to the activity of your belonging branch office?
Q2. Please rate the degree of satisfaction to the activity of the area manager in your belonging branch office?
Q3. Please rate the degree of satisfaction to the activity of the seminar manager in your belonging branch office?
Q4. Please rate the degree of satisfaction to the activity of the intern manager in your belonging branch office?
Q5. Please list up to three contributors in your belonging branch office?

Note that all answers were asked to select from five alternatives (1:Very satisfied, 2:Satisfied, 3:Neutral, 4:Not satisfied 5:Not satisfied at all).

5.2 Achievement Rate

The activity for each branch office is numerically evaluated by comparing the total number of students coming to seminars and diet members accepting intern students with the desired number set at an early stage of each period. Mathematically, the achievement rate is measured by the following equation.

$$Achievement\ rate(\%) = \frac{x}{y} \times 100 \tag{11}$$

where

x : *actual number of students and diet members*

y : *desired number of students and diet members*

5.3 Assumptions for Leadership Behaviors

The results of questionnaire survey (Q1, Q2, Q3, and Q4) and the achievement rate for each branch office are shown in Table 1. To understand the relationships between the degree of satisfactions and achievement rates, the branch offices are classified into three groups based on the achievement rates.

Group-1: The group of high achievement rate, including Branch-A, Branch-B, and Branch-C. Staffs in Branch-A and Branch-B have high degree of satisfaction to both their branch office and area manager. On the other, staffs in Branch-C have high degree of satisfaction to their branch office but low degree of satisfaction to their area manager.

Table 1. Achievement rate and averaged degree of satisfaction for each branch office, area manager, seminar manager, and intern manager.

Branch	Achievement rate (%)	Averaged degree of satisfaction (5:Very satisfied, 4:Satisfied, 3:Neutral, 2:Not satisfied, 1:Not satisfied at all)			
		Branch	Area mgr.	Seminar mgr.	Intern mgr.
Branch-A	135	4.78	5.00	5.00	4.79
Branch-B	109	4.37	4.37	4.25	4.00
Branch-C	106	2.69	3.00	4.56	4.62
Branch-D	97	3.58	4.50	2.75	4.00
Branch-E	99	2.69	2.75	3.94	2.94
Branch-F	79	2.87	3.69	3.04	4.31
Branch-G	69	2.82	4.50	3.80	1.70

Group-2: The group of middle achievement rate, including Branch-D and Branch-E. The degree of satisfaction to area manager in Branch-D is quite high compared to the one in Branch-E.

Group-3: The group of low achievement rate, including Branch-F and Branch-G. The degree of satisfaction to area manager in Branch-G is much higher than the one in Branch-G.

The types of groups above are considered not to reflect the management ability of area managers because the achievement rates were considered to affect the degrees of satisfaction to area managers, i.e., high achievement rate gives a positive affect to the degree of satisfaction, and vice versa. However, the degrees of satisfaction within the same group are considered to reflect most of the management ability of area managers since it excludes the effect related to the achievement rate. By comparing the branch offices in the same group but have different degrees of satisfaction to area managers, four assumptions regarding the management ability are made as follows.

Assumption-1: High degrees of satisfaction to the area managers in Branch-A, Branch-B, Branch-D, and Branch-G imply the high level of their management abilities.

Assumption-2: Low degree of satisfaction to the area manager in Branch-C reflects the lack of his management ability.

Assumption-3: Low degree of satisfaction to the area manager in Branch-E comes from the lack of his management ability.

Assumption-4: High degree of satisfaction to the area manager in Branch-G comes from the high level of his management ability.

To estimate the assumptions above, 10 staffs were interviewed individually in face-to-face and made sure that the assumptions were getting to the point, i.e., area managers of Branch-C, Branch-E, and Branch-F were not trusted regarding management ability, whereas area managers of other branches won staffs' esteem. In the following sections, leadership behaviors were further investigated by comparing influential human networks obtained from the archives of E-mail with these assumptions.

6 Influential Human Networks

6.1 E-mail Archives

The activities such as seminars and events are held in the field, but many important things such as information sharing, decision making, event planning, and consensus building are carried over E-mails. Area managers are in charge of the affairs on E-mails as opposed to seminar and intern managers operating in the field. Therefore, leadership behaviors of area manager would be reflected on the influential human networks extracted from the archives of E-mail.

Table 2 shows the overview of E-mail archives in seven branch offices of the 14th period (from October 2004 to March 2005) to be analyzed in this project. The E-mails are written in Japanese. Before applying the IDM to the archives, JUMAN[5], morphological analysis system, are used to obtain terms of noun, verb, and adjective, and then remove noise words (or "stop words"[11]) to measure the influential and influenced values accurately. The list of noise words were manually made in advance from the results of the pretest of the analysis.

6.2 Verification of Assumptions

The IDM is applied to the archives of E-mail in each branch office respectively to obtain $I_p^{<1>}$ and $I_p^{<2>}$ as an influential and influenced value of each staff. The top six staffs by $I_p^{<1>}$ for each branch office are shown with $I_p^{<2>}$ in Table 3, where the same staff names across branch offices represent distinct staffs[6]. The staff names with "*"(asterisk mark) represent area managers.

Table 2. The number of staffs and E-mails exchanged on the 14th period (October 2004 – March 2005).

	Branch-A	Branch-B	Branch-C	Branch-D	Branch-E	Branch-F	Branch-G
# of staffs	21	9	16	14	16	16	12
# of E-mails	2297	1198	2465	2076	3258	1309	1717

[5] http://www.kc.t.u-tokyo.ac.jp/nl-resource/juman.html (Japanese web site only)
[6] For example, p1 in branch offices represents distinct staffs.

Table 3. For each branch office, the top six staffs by $I_p^{<1>}$ are shown with $I_p^{<2>}$. Note that the same staff names in different branches represent distinct staffs, and the staff names with "*"(asterisk mark) represent area managers.

Staff in Branch-A	$I_p^{<1>}$	$I_p^{<2>}$	Staff in Branch-B	$I_p^{<1>}$	$I_p^{<2>}$	Staff in Branch-C	$I_p^{<1>}$	$I_p^{<2>}$
p2*	541	827	p1*	841	385	p6	1113	403
p39	518	0	p9	772	1051	p1*	836	142
p18	506	177	p5	542	317	p8	515	1257
p4	470	244	p2	484	666	p18	490	95
p41	454	910	p11	304	198	p2	470	163
p5	417	235	p17	251	537	p17	405	261

Staff in Branch-D	$I_p^{<1>}$	$I_p^{<2>}$	Staff in Branch-E	$I_p^{<1>}$	$I_p^{<2>}$	Staff in Branch-F	$I_p^{<1>}$	$I_p^{<2>}$
p1*	1495	717	p4	1022	8	p11	578	524
p4	923	68	p3	1019	1032	p20	506	871
p13	893	1880	p11	754	563	p18	432	52
p3	794	927	p7	737	664	p1*	404	263
p5	790	386	p1*	686	849	p16	355	98
p14	655	205	p2	560	491	p28	325	0

Staff in Branch-G	$I_p^{<1>}$	$I_p^{<2>}$
p3	779	1270
p4*	559	623
p6	537	36
p8	521	466
p1	513	480
p28	445	0

From Table 3, following tendencies are observed.

- Three out of seven area manages have the highest $I_p^{<1>}$ in their belonging branch offices.
- Those who have high $I_p^{<1>}$ are not always have high $I_p^{<2>}$, and vice versa.

To investigate further based on four assumptions in Section 5, $I_p^{<1>}$ and $I_p^{<2>}$ are compared with the results of Q5 of the questionnaire survey where staffs are asked to vote for up to three staffs to be outstanding contributors. The number of votes represents how much the management ability of a staff is evaluated regardless of his/her position. The rankings of area managers by vote, $I_p^{<1>}$, and $I_p^{<2>}$, shown in Table 4, support Assumption-1, that is, area managers having high $I_p^{<1>}$ and $I_p^{<2>}$ tend to obtain a number of votes in Branch-A, Branch-B, Branch-D, and Branch-G.

Table 4. Achievement rates and rankings of area managers for each branch office.

	Ranking of area manager		
Branch	Vote	$I_p^{<1>}$	$I_p^{<2>}$
Branch-A	1	1	3
Branch-B	2	1	4
Branch-C	N/A	2	14
Branch-D	2	1	6
Branch-E	4	5	4
Branch-F	N/A	4	8
Branch-G	1	2	3

On the other hand, area managers in Branch-C and Branch-F did not obtain any vote. In these cases, the medium rankings of $I_p^{<1>}$ (2nd in Branch-C and 4th in Branch F) and the low rankings of $I_p^{<2>}$ (14th in Branch-C and 8th in Branch F) are identified. Considering the results with Assumption-2, the lack of management abilities of area managers in Branch-C and Branch-F arises from their low level of $I_p^{<2>}$, i.e., they hardly replied back to the E-mails sent by the other staffs.

As for Assumption-3, $I_p^{<1>}$ of area manager in Branch-E ranked much lower than that of in Branch-D whereas the rankings by $I_p^{<2>}$ were almost the same. The low degree of satisfaction to the area manager in Branch-E is considered to come from his low level of $I_p^{<1>}$, i.e., he hardly sent useful E-mails to the other staffs.

In Branch-G, the area manager ranked 1st by votes, and ranked high as well by $I_p^{<1>}$ and $I_p^{<2>}$ although the achievement rate was the worst. From this result and Assumption-4, the degree of satisfaction to the area manager in Branch-G is considered to comes from his high level of $I_p^{<1>}$ and $I_p^{<2>}$, i.e., he interactively communicated with the other staffs on E-mails.

In summary, high $I_p^{<1>}$ and $I_p^{<2>}$ is the qualification that area managers should be required. As leadership behaviors, area managers should send useful (constructive or helpful) E-mails for getting high $I_p^{<1>}$ and reply back to the E-mails sent by the other staffs as much information as possible for getting high $I_p^{<2>}$.

6.3 Interpretation of Influential Human Networks

The graphical outputs of influential human networks help us understand the behaviors of area managers from structural point of view. Figure 3, Figure 4, Figure 5, Figure 6, Figure 7, Figure 8, and Figure 9 are the graphical outputs of the IDM obtained from the archives of E-mails of Branch-A, Branch-B, Branch-C, Branch-D, Branch-E, Branch-F, and Branch-G respectively. Here, the figures are composed of top six influential staffs and influential links between them with more than 10 influential values because of the simplicity

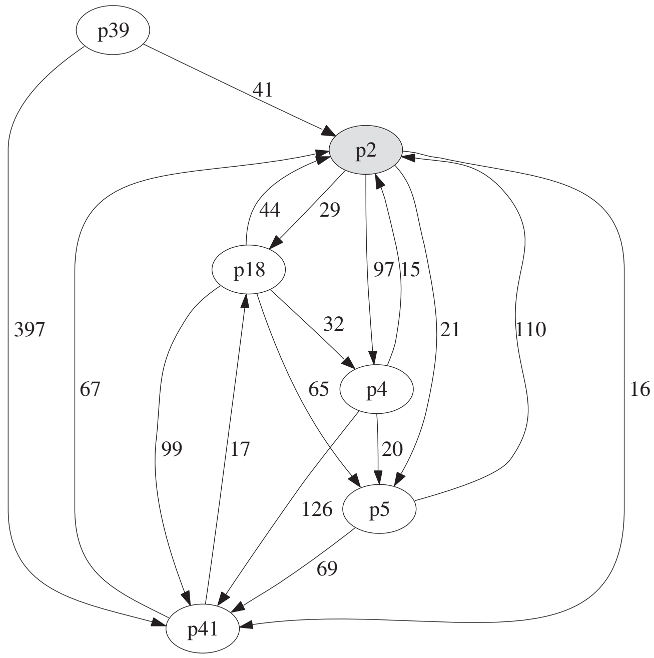

Fig. 3. An influential human network in Branch-A.

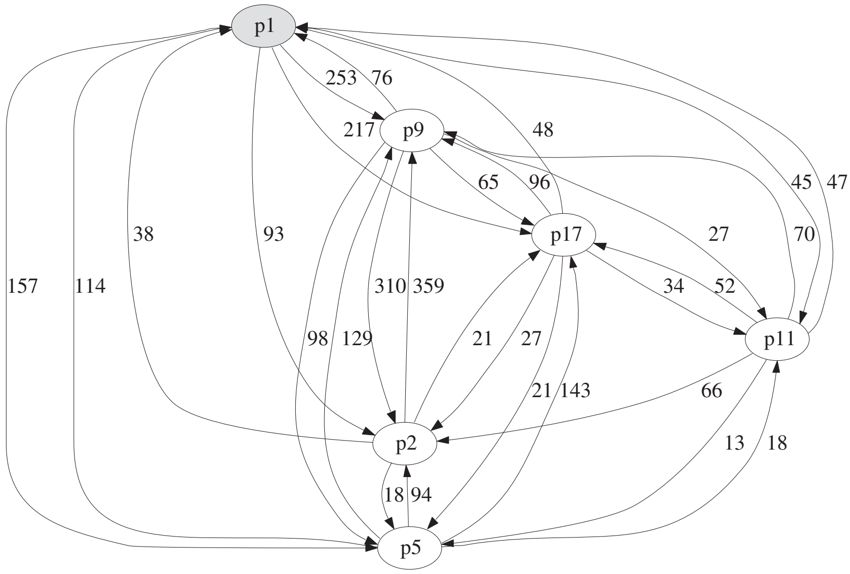

Fig. 4. An influential human network in Branch-B.

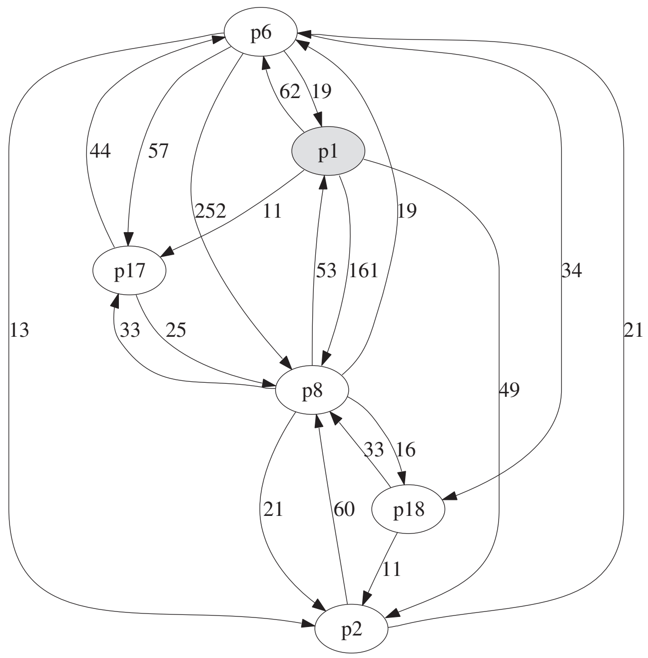

Fig. 5. An influential human network in Branch-C.

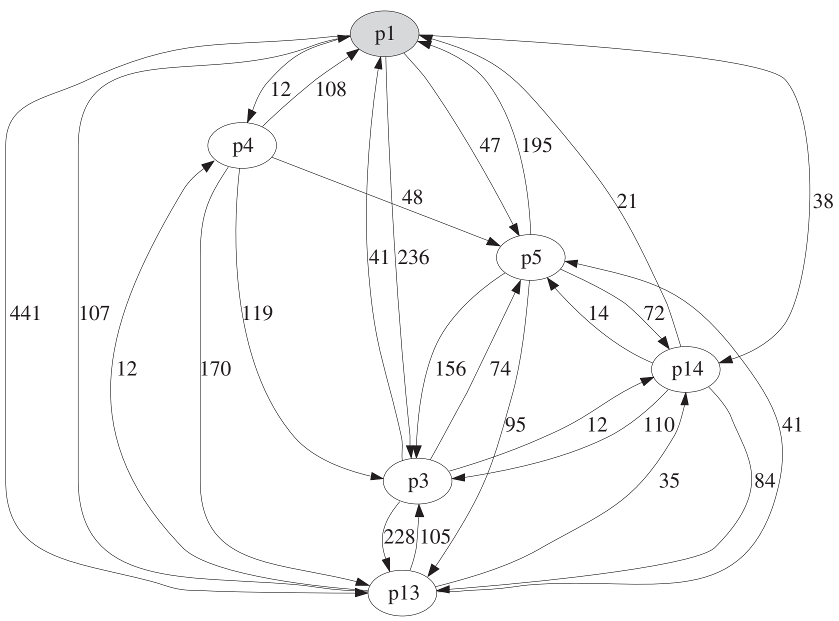

Fig. 6. An influential human network in Branch-D.

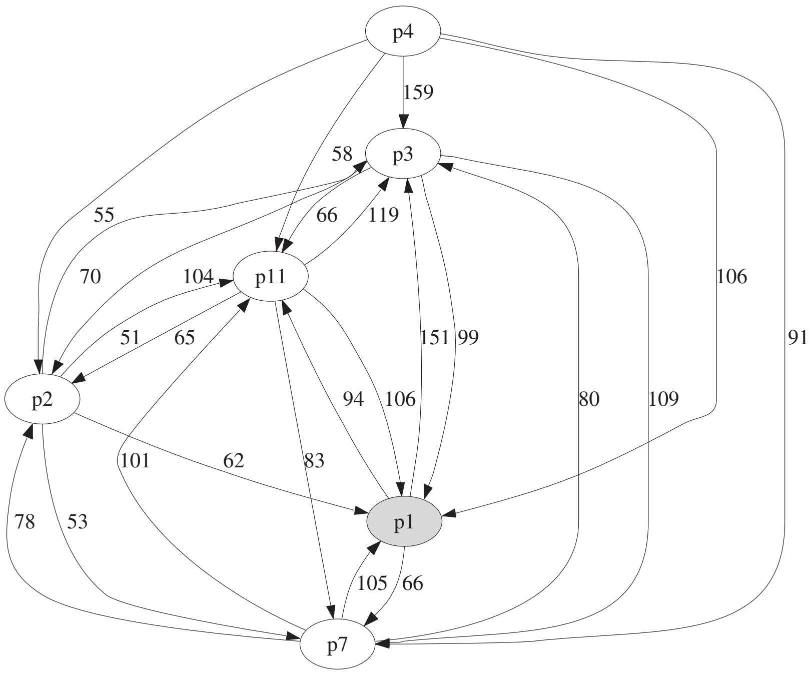

Fig. 7. An influential human network in Branch-E.

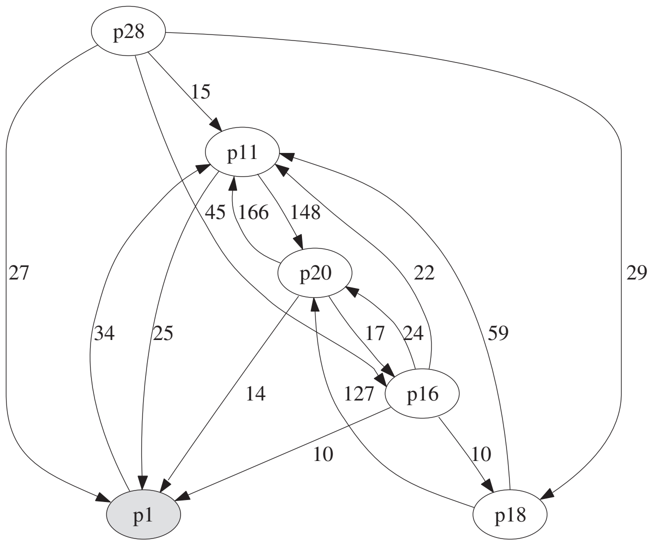

Fig. 8. An influential human network in Branch-F.

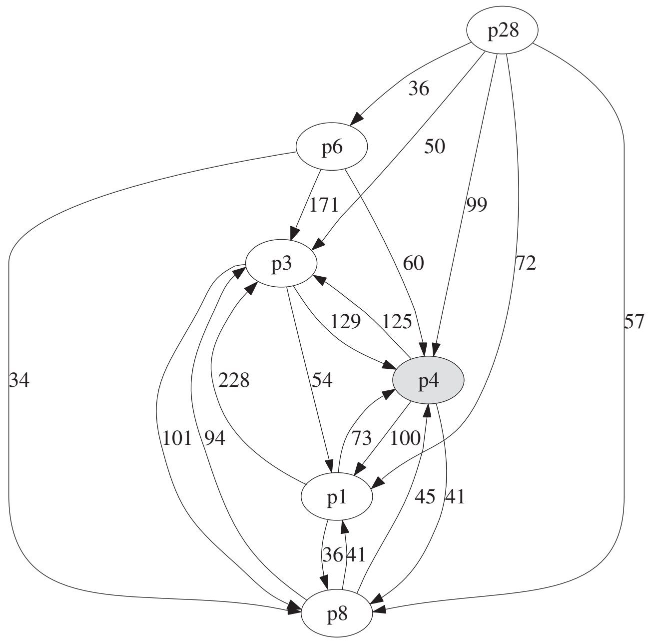

Fig. 9. An influential human network in Branch-G.

of the figures. In the figures, area manages are depicted as gray nodes, and the influential relationships between staffs are shown as directed links with influential values. The figures visualized the behaviors of area manages to the other staffs. In the followings, the leadership behaviors interpreted based on influential human networks and the analysis of questionnaire survey are summarized.

Interactive behavior: In Figure 3 of Branch-A, Figure 4 of Branch-B, and Figure 6 of Branch-D, the behaviors of the area manages are "interactive" enough to give and receive influence from the other staffs. Questionnaire survey also points out that the area managers are highly trusted.

Partly interactive behavior: In Figure 7 of Branch-E and Figure 9 of Branch-G, the behaviors of the area managers are "partly interactive" where the area managers receive influence from five staffs while give influence to selected three staffs. From the results of questionnaire survey, the reason that the area manager in Branch-G succeed in managing Branch-G is considered to come from his high influential and influenced values. On the other, the area manager in Branch-E failed because of his low influential and influenced values compared to his colleagues.

Preferential behavior: In Figure 5 of Branch-C, the behavior of the area manager is "preferential", meaning more strict than partly interactive behavior, where the area manager gives influence to four staffs, and receive influence from only two staffs. The lack of his interaction, especially comes from his low influential values, is considered to result in the fault of managing Branch-C.

Passive behavior: In Figure 8 of Branch-F, the behavior of the area manager shows rather "passive" where the area manager receives influence from four staffs although gives influence to only one staff. The apparent lack of communication is considered to bring the distrust of the area manager in Branch-F.

From the results so far, it is concluded that interactive behaviors are the ideal leadership behaviors that area managers are expected to have.

By relating the interpretation of influential human networks to $I_p^{<1>}$ and $I_p^{<2>}$, the types of leadership behaviors are approximately identified as follows.

$$Type\ of\ behavior = \begin{cases} Interactive & (high\ I_p^{<1>}\ and\ high\ I_p^{<2>}) \\ Partly\ interactive & (middle\ I_p^{<1>}\ and\ high\ I_p^{<2>}) \\ Preferential & (high\ I_p^{<1>}\ and\ low\ I_p^{<2>}) \\ Passive & (low\ I_p^{<1>}\ and\ high\ I_p^{<2>}) \end{cases}$$

The classification above provides the possibility of the other behavioral types, such as $high\ I_p^{<1>}\ and\ low\ I_p^{<2>}$, but further research is needed to figure it out.

7 Predictability of Human Behaviors

If the behaviors of staffs could be predicted, it would be useful when a new area manager is elected at the beginning of each period. In this section, the predictability of staffs' behaviors is investigated by plotting how $(I_p^{<1>} - I_p^{<2>})$ of 56 staffs working on both the 13th period (April 2004 - September 2004) and the 14th period (October 2004 - March 2005) changes across the periods.

Figure 10 shows a scatter plot where x-axis and y-axis indicates $(I_p^{<1>} - I_p^{<2>})$ in the 13th period and the 14th period respectively, and a cross-shaped point corresponds to a staff. In Figure 10, the cross-shaped points are roughly in direct proportion between the 13th period and the 14th period (the correlation is 0.48). The upward line on Figure 10 obtained by linear regression method also visually shows the tendency.

In addition, the first quadrant in Figure 10 can be interpreted that the staffs whose $I_p^{<1>}$ exceeds $I_p^{<2>}$ in the 13th period tend to keep the same tendency in the 14th period. Similarly, the third quadrant suggests that the staffs whose $I_p^{<2>}$ exceeds $I_p^{<1>}$ in the 13th period also tend to have the same tendency in the 14th period. The origin of coordinates indicates that the staffs whose $I_p^{<2>}$ and $I_p^{<1>}$ are balanced in the 13th period are inclined to be balanced in the 14th period as well. That is to say, it is better to elect an area manager from those who have high $I_p^{<2>}$ and $I_p^{<1>}$ in the previous

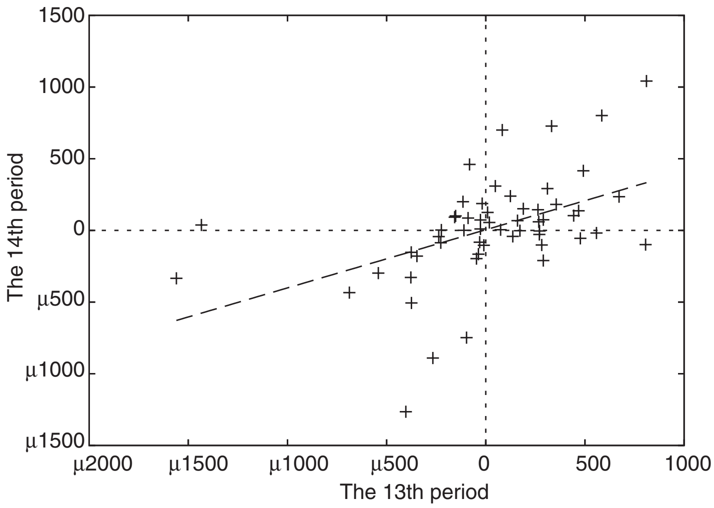

Fig. 10. A scatter plot of $(I_p^{<1>} - I_p^{<2>})$ of 56 staffs working on both the 13th period (April 2004 - September 2004) and 14th period (October 2005 - March 2005).

period if you want to reduce the risk of getting a powerless leader because the behaviors of staffs do not easily change.

8 Conclusion

The activity of NPO is based on the staffs' voluntarism, however staffs often lose it and eventually leave the organization. Part of the reason comes from staffs' unsatisfactory to the lack of leaders' management ability. This study proposed an approach to integrate questionnaire survey and the IDM analysis, and found out ideal leadership behaviors that a leader should acquire as management abilities.

As you might already realize, a chance in this chapter corresponds to a deep understanding of human society from point of influential relationships. Of course the approach introduced here can be applied to any organization, the communication is done in a variety of ways for each organization and accordingly the approach for discovering a chance needs to be modified. I believe the readers of this book can invent their own approaches and discover chances from the communication you are involved or interested in.

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Resonance without Response: The Way of Topic Growth in Communications

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Summary. An on-line and a real-space communication, were visualized using two methods, KeyGraph and DSV+IDM. For a text data of communication, KeyGraph presents the overview of bridges between topics in the communication, whereas IDM/DSV shows the flow of topics in each chain of responses from/to messages. In this paper, for each community, observing the KeyGraph and its changes with the time of communication progress, compared with IDM, we observed how topics grow. Result: The strongest topic, corresponding to the deepest chain, grew up via the conflictions and consensus among strong chains. However, the interactions were not made on the response from a message to others, but on the reference to some new words in other chains in from the communication in their own chain. This implies weak common concerns between multiple sub-communities, rather than explicit responses, is the cause of topics growth in communications.

1 Introduction: Enthusiasm in Communication as the Source of Value

In companies, the value of a product is usually pre-estimated by marketers, before the product gets commercialized. This estimation may come from the response of consumers to questionnaire surveys, and the product will be thrown in the market on the confidence that customers will like it. However, it is difficult to identify when and who created the idea underlying the product.

In some cases, an intuitive innovator employed by the company may propose a product keenly hitting the interest of consumers. In other cases, an innovative user may make a scenario of user's consumption of the product and distribute it to his/her friends [1]. The company can also hire such a leading user - this is a mixed model of consumer-driven and innovator-driven value diffusions. That is, a valuable scenario may start from the mind of someone, and propagates via the communication of consumers to all over the market.

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In such a classical model of diffusion as [2], however, the propagation process causes no change in the created scenario or its value.

However, in reality, the process of idea-propagation itself often makes new values obviously [6]. For example, a new way of using an existing product may become created by a user, when he/she hears about the product. Even a strong advertisement from the side of promoter can be revised when the promoter is aware of such a creative user. However, a problem remains. How can the idea grow highly influential, without a media for broadcasting the user's voice? Usually, the media for such a voice is a local communication rather than mass media. This motivated us to rise the problem dealt with in this paper: how does a communication in a local community make a message influential?

In this paper, An on-line and a real-space communication, were visualized using two tools, KeyGraph [5] and DSV+IDM [3]. KeyGraph presents the overview of the bridges between topics in the communication, whereas DSV+IDM shows the flow of topics. The flow in the latter is shown with arrows, where each arrow represents a response from a message to a previous message. A connected graph made of nodes corresponding to messages and arrows between them is called an influence chain, or a chain simply in this paper.

Observing the changes of KeyGraph with time, comparing with IDM, the growth of topics in the subject communities is analyzed in this chapter. A strongest topic, corresponding to the deepest chain, grows up via its interaction with other strong chain. However, this interaction is not usually made on the explicit response from a message to others, but rather on the reference to words in other chains from the communication within one chain. This implies the weak sharing of common concerns among multiple sub-communities is the cause of topic growth in communication.

2 The Problem: Is Responses the Core of Opinion Creation?

In human society, there is a latent assumption that a response to a message is the strongest evidence of the interest of the responder, in the message he/she is responding to. If this assumption is valid, looking at the responses in a message board should be the most promising approach to understanding the interest of participants.

However, we cast a question in this paper: "Does meaningful ideas rise from participants' responding to each other?" That is, as in Fig. 1, the topic propagates from a participant to another participant not only via message-response relation. That is, one may catch a word of somebody talking to somebody else in the same room, and begin to talk about a topic relevant to the word. This occurs if one has a potential concern with the topic. If this

Fig. 1. Resonance with (right) and without (left) responses. In the left figure, the two pairs are talking individually, but hearing the talk of each other. Soon all the four begin to talk about common topic "beer." In the right, two people talking to each other are sharing words to use.

kind of indirect response to a message is a strong source of rising interests in a community, we should take care of more implicit expressions of interests in the community, than responses in explicit replies.

Here let us introduce a definition below, of "resonance" for expressing the complex concept in a single word. The aim of this paper is to show our finding that a strong resonance occurs, between a pair of chains without response to each other.

[Definition] Multiple message chains are said to make a resonance, if a new and more influential topic than those chains appears due to the co-existence of those chains.

3 The Analysis Methods: KeyGraph and IDM/DSV

In this section, we apply two methods called KeyGraph [5] and IDM [3]. DSV (Discussion Structure Visualization) is a tool for visualizing the message chains, where the response from one message to another is depicted with an arrow. DSV+IDM marks the influential messages among those depicted by DSV on the computation by IDM (Influence Diffusion Model). On the other hand, KeyGraph shows bridges between clusters of co-occurring words. This corresponds roughly to the relation between multiple message chains, via some words shared in the interaction between multiple chains without response to each other.

Here, let text D be the communication about critical scenarios in the future of a company, as in Eq. (1), and see what IDM/DSV and KeyGraph can show out.

D = " *Mr. A: In the market of general construction, the customers decreased.*
Mr. B: Yes$\cdots$ Our company, building from concrete and steel, is in this bad trend.
Mr. C: This state of the market induces a further decrease of customers. Our company may have to introduce restructuring for satisfying customers.
Mr. B: Then the company can reduce the price of concrete, steel, and construction.
Mr. D: But that may reduce the power of this company."

[DSV+IDM]

In DSV, the content of a communication in a group of people is first segmented into messages. In case delimiters between segments are not given in advance, each pair of serial sentences are included in the same segment, if their words are similar. If they are not similar, they are included in different segments. If the target text is a content of communication, each segment usually corresponds to a message. After segmentation, the influence strength between each pair of segments, which appeared in close locations to each other, is computed on the number of words shared by the pair of segments. For example, if a message on the decision to go out for beer appears just after the proposal to go for beer, the former is regarded as the response to the latter, because the segments (i.e., messages) share words such as "drink" and "beer" and appeared close to each other.

And, IDM [3] computes the influence to the community from of each message visualized in DSV. In IDM, the response strength from one message X to a preceding one Y, called influence rate, has been defined as the rate of words shared between X and Y, among for all words in X. Some parts of the communication become enthusiastic with responses between messages including frequent words in the community, but these parts can be bridged by temporary messages using rare words. As a side effect, it becomes possible to show different meanings of a single word by visualizing its appearance in different messages Fig. 2 shows the result of IDM/DSV for the communication in Eq. (1).

[KeyGraph : The procedure of making a map of concepts]

KeyGraph is a computer-aided tool for visualizing the map of event relations in the environment, in order to aid in the process of chance discovery. If the environment represents a place of discussion, an event may represent a word uttered by a participant. By visualizing the map where the words appear connected in a graph, one can see the overview of participants' interest. For being more specific, suppose text (string-sequence) D is given, describ-

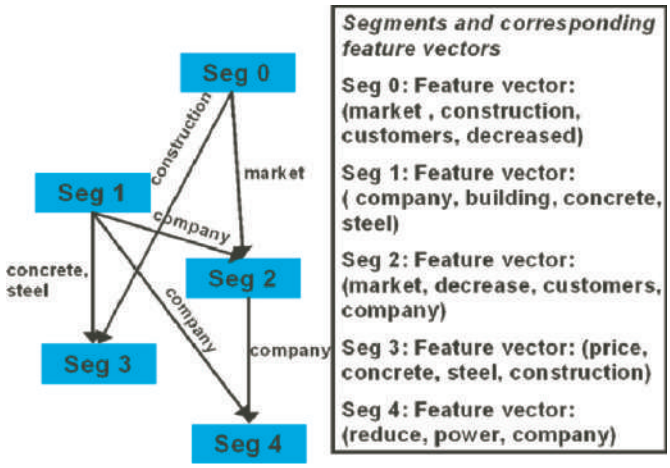

Fig. 2. An output example of IDM/DSV, for the messages in Eq. (1).

ing an event-sequence sorted by time, with periods (".") inserted at parts corresponding to the moments of major changes.

In the case of Eq. (2), periods are put at the end of each sentence. In the case of a sales (Position Of Sales: POS) data, periods can be put in the end of each basket. *KeyGraph*, of the following steps, is applied to text D. Seeing Fig. 2.

KeyGraph-Step 1: Items appearing many times in the data (e.g., the word "market" in Eq. (2)) are depicted with black nodes, and each pair of these items occurring often in the same sequence unit (a sentence in a document, a bought set of items in each basket in sales data, etc) is linked to each other, e.g., " steel - concrete - company" for Eq. (2) with a solid line. Each connected graph obtained here forms one *island*, implying a common context underlying the belonging items.

KeyGraph-Step 2: Items which may not be so frequent as the black nodes in islands but co-occurring with multiple islands, e.g., "restructuring" in Eq. (2), are obtained as *hubs*. A path of links connecting islands via hubs is called a *bridge*. If a hub is rarer than black nodes, it is colored in a different color (e.g. red or white). We can regard such a new hub as a candidate of *chance*, i.e., items significant for decisions to go from/to islands.

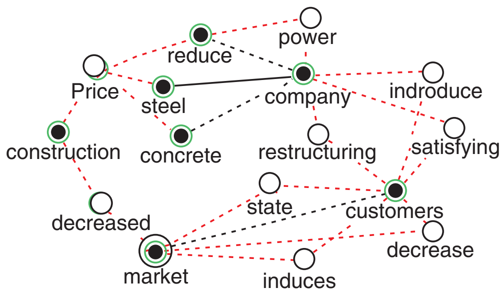

Fig. 3. An example of *KeyGraph on Polaris*: Islands are obtained from D in Eq. (2), each including event-set {market}, {steel, concrete, company}, {customers} etc. The double-circled nodes and white nodes show frequent and rare words respectively, forming hubs of bridges.

4 Results: Resonance without Response

4.1 Result 1: Discussion about Young Peoples Current Usages of Information

In this section, let us show combined results of IDM/DSV and KeyGraph, for two different data of communications. One is from a real-space discussion in an interdisciplinary research meeting, and the other is from an on-line community where people are sending messages about a top-sales Japanese brand of tea in can. We assume these are two extreme cases, in the sense below:

1) In the former group, participants recognize each other face-to-face and they are talking on a specific research issue "what are the problems in the current usage of information of young people?" where participants should focus attention to a restricted interest from various background domains.
2) In the latter group, participants are totally anonymous, and their topic is known to wide range of Japanese consumers. Anybody can join the community, and they do not have a duty to focus attention to a certain aspect in talking about the popular product.

That is, the group in 1) is a limited number of people talking about limited topic, knowing who are in the group. And, 2) is an unlimited community in these aspects.

Looking at the result in Fig. 4, for the former group: The communication begins from the left-most message chain Block 1. It shifts from Block 1 to Block 2, but do not return to Block 1 i.e., people never responded to messages in Block 1 after this shift. On the other hand, we find both-way transitions between Block 2 and Block 3, and then influential messages (segments in red nodes) began to appear just after this transition stopped at the segment marked "Anonymity" in the middle of Block 3. After this, their topic changed from human behaviors on the Internet to more general behaviors including the real space life.

From this result of IDM/DSV, we found the both-way transitions between message chains created a new and influential context. And we also found the two message chains in such a relation lasted the longest among all chains in the communication. It is obvious that this relation is not made of responses to each other, because there is no arrows shown by DSV, corresponding to responses, between the two chains.

Yet, we can not say we showed a evidence of resonance without response, unless we show the concepts were born from the both-way interaction between the two chains in Fig. 4, and that these concepts are really linked to the influential messages leading to Block 4. For showing this evidence, let us show the result of KeyGraph for the same content of communication as follows.

As in Fig. 5, there are islands (clusters of frequent words, co-occurring frequently with each other) corresponding to Blocks 2, 3, and 4. Block 3 is found to include two islands, and both of these sub-blocks are linked to Block 2, via rare words. That is, the concept "empathy" and "good will" is bridging between Block 2 and Block 3-a. Considering the basic concepts in these blocks, the appearance of "empathy" is reasonable: Block 2 was about "information ethics" and Block 3-a was about the "attitudes to other people," and "empathy" appeared as a solution to solve both "unethical behaviors on the Internet" and "bad attitudes to other people" of young people. The co-occurrence of "empathy" and "good will" with the messages in the two blocks were really detected by looking in the text of the communication. The messages were all about young people's behavior, corresponding to the "behavior" in Fig.5. And, the concept "rational egoists" is bridging between Block 2 and

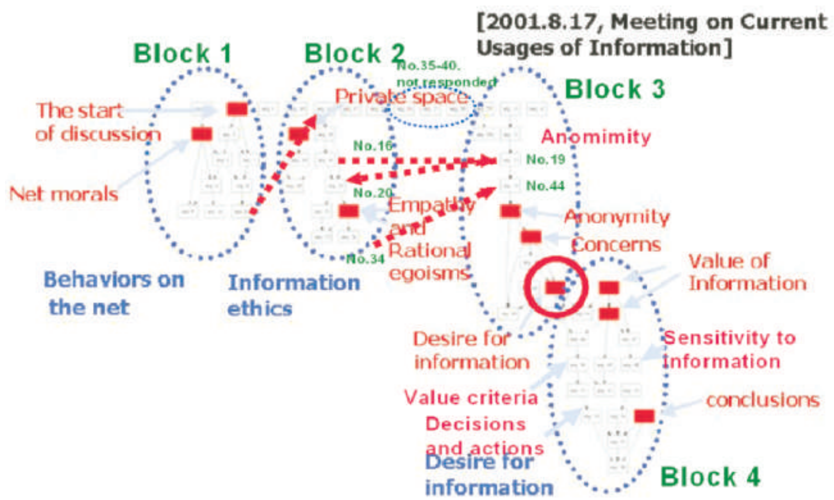

Fig. 4. The message chains for a group discussion about information ethics. The thick arrows were attached manually, showing the order of messages not linked via massage-response relations, by author on the output of IDM/DSV for this paper.

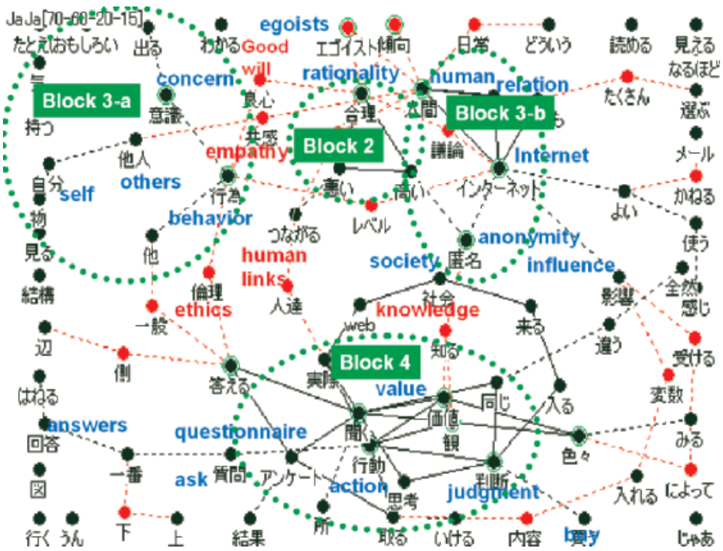

Fig. 5. Links between the four blocks in Fig. 2. The finally appeared Block 4 rose from Block 3, which contained two separate contextual clusters Block 3-a and Block 3-b coming from Block 2. In other words, Block 4 is the grandchild of Block 2.

Block 3-b. A rational egoist means a person who does evil things as far as people do not identify who did those things. It is understandable that this came to appear as a concept relevant to both Block 2 and Block 3-b including "human relations." We also find "Anonymity" came from between Block 2 and Block 3-b in Fig. 5.

Among these bridges, we find "anonymity" and "behavior" are also linked to Block 4. These are the frequent words bridging between Block 2 and 3, and this frequency is due to the number of times of these words used in Block 4. However, messages including these words were not messages in Block 2 responding to Block 3 or vise versa.

The evidence in Fig. 6 is more clear, because it shows the birth of a concept at a time of communication always becomes the trigger of a new topic linked to itself. For example, "daily life" in 2) grows to "shopping" in 3), and the topic "quetionnaire" in 3) grows to the main topic in 4). As well as in Fig. 5, these words were born in messages on the inter-chain topics, but not in response from one chain to another.

4.2 Result 1: On-line Communication about a New Japanese Tea Brand

The next community we dealt with is an online-community from "2 channel" site, (http://www2.2ch.net/) made of 780 messages for 30 weeks. The 30

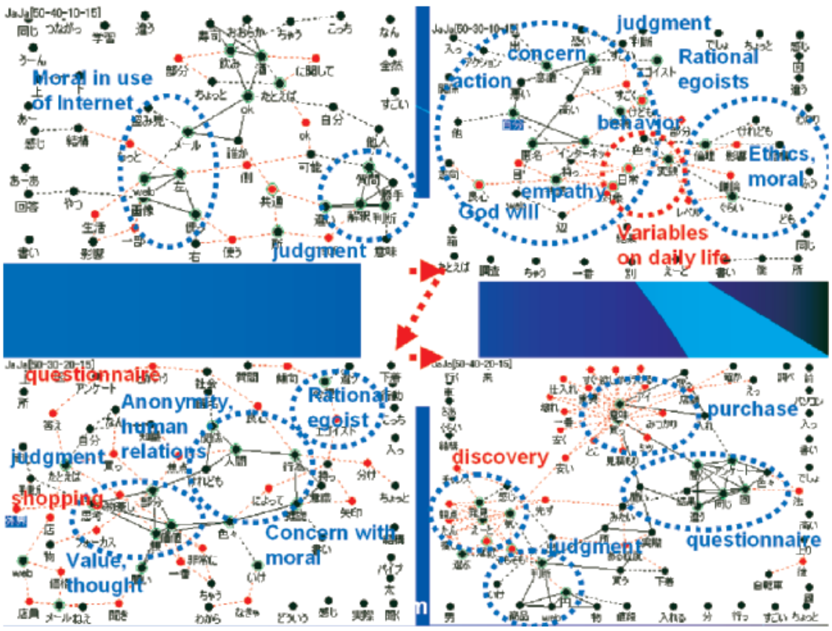

Fig. 6. The temporal changes of the visual summary (KeyGraph) of the first, second, third, and the forth (last) quarter of the overall amount (i.e., 25% of lines) of communication.

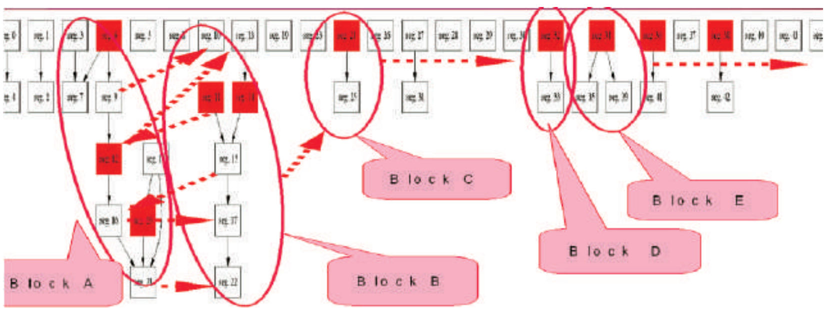

Fig. 7. The Result of IDM, for an on-line community discussing about a soft drink in Japan.

weeks began from one week after the relies of the CM of a Japanese brand of can-tea. The overall communication was segmented into 49 segments. On the way of their communications, all participants had their names hidden, and used nicknames as the identification. However, the potential changes in the nicknames forbid us from estimating the number of participants. Thus, the number of participants is unknown.

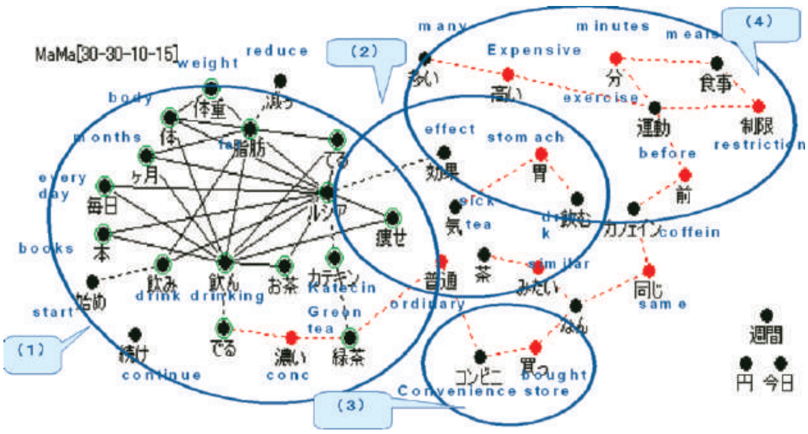

Fig. 8. The words from the 30 weeks communications of consumers.

The result of IDM/DSV is as in Fig. 7. We find five major blocks of chains:

Block A: The effect of catechin to the reduction of fat, i.e., dieting.
Block B: The side-effect of catechin, e.g., metabolism of various substances.
Block C: Claims for the high expense.
Block D: Claims that the tea is only sold in convenience stores.
Block E: Care of other methods of dieting, than taking catekin.

Two of the deepest chains, Block A and Block B, are found to have been interacting with each other as in the case of Block 2 and Block 3 in result 1. Then, smaller chains such as Block C, D, and E appeared, among which the interaction is not detected neither as responses to each other or as a progress of conversation at the same time as Block A and Block B.

On the other hand, the result of KeyGraph for all the messages combined as a document is shown in Fig. 8. Here, each part of KeyGraph is found to correspond to each block in IDM/DSV. Although the result of IDM/DSV had no link between two or more chains, we recognize the following areas including bridges between blocks of IDM/DSV, in KeyGraph.

Area (1): The effect of Catekin to the reduction of fat. Corresponds to A.
Area (2): Feeling of the side effects in drinking the tea. Relevant to B, but also contains negative claims of the side effects.
Area (3): The places to buy the tea: For example, it is not a good situation that only convenience store can supply this product. Corresponds to Block C and D.
Area (4): Skeptical opinions on the aspect of dieting. Corresponds to Block E.

Thus, we find Block (2) is bridging the positive comments about the tea (Block(1)) and the negative/skeptical comments (Block(3) and Block (4)).

This implies there was resonance between Block A and Block B, respectively corresponding to Block (1) and Block (2), triggered the birth of Block (3) and Block (4). In this case, again, there was no responding relation between messages in Block A and Block B in IDM/DSV.

5 Conclusions

In the exemplified results, the resonance without response enables creative thoughts in a groups of people. The two methods for visualizing textual data, i.e., KeyGraph and IDM, showed out figures, of which the combinations clarified the role of resonance without response in the growth of topics in communication.

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Scenario to Data Mapping Algorithm and Its Application to Chance Discovery Process Support

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Summary. The mapping method between the graph generated by KeyGraph and the scenario drawn up by a user is proposed for supporting chance discovery process. Although KeyGraph is widely known as one of the effective tools that support the process of chance discovery, further improvement seems to be required, concerning the ambiguity involved in user's interpretation of the graph. The mapping found by the proposed algorithm is used for extracting the data referred to in the scenario and for annotating those in the original data file. The annotated data files are expected to be used for further data analysis as well as for supporting group discussion. As one of the possible applications, an experiments is performed in terms of scenario similarity calculation based on the annotated data set, of which the result is compared with typical document retrieval method based on VSM (Vector space model). Furthermore, new KeyGraph is generated from a data subset extracted based on the annotation. Those results show the availability of annotated data in chance discovery process.

1 Introduction

The mapping method between the graph generated by KeyGraph [4] and the scenario, which a user draws up from the graph, is proposed for supporting chance discovery process. The KeyGraph, which visualizes the hidden structure within the data set with a metaphor of islands and bridges, is widely known as one of the effective tools for supporting the process of chance discovery. However, further improvement seems to be required for resolving the ambiguity involved in user's interpretation of the graph.

The proposed method is considered as a kind of "smart data" approach [1] in the sense that the original data set used as the input to KeyGraph is annotated based on the mapping between the scenario and the graph. The proposed

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mapping algorithm extracts the set of bridges and islands that are referred to in the scenario, each of which is represented as a set of keywords. The extracted bridges and islands are translated into logical expressions, which are used for finding the corresponding baskets in the original data set. Section 2 discusses the smart data approach for chance discovery process, and the algorithm is proposed in Section 3. Through the experiment in Section 4, the availability of the proposed method in chance discovery process is shown in terms of scenario similarity calculation as well as data subset extraction for generating new KeyGraph.

2 Smart Data Approach for Chance Discovery

2.1 Roles of Computer Systems in Chance Discovery Process

Chance discovery process generally involves the interaction between humans and computer systems. Computer systems help humans understand the data collected from a domain of interest, and make decisions for business, research, etc. Typical tasks that are performed by the computer systems are data mining and information visualization. In general, data mining is a task that extracts general rules or abstract information from huge data set in terms of predefined criterion. In other words, typical data mining techniques find the information supported by a large number of data, which is useful for prediction in a stable environment. However, using only data mining techniques is not enough for chance discovery, because its aim is different from prediction based on general rules. That is, the word 'chance' means information about an event or a situation that is significant for making decisions [3], and such event or situation is usually a rare one.

As the saying "a chance favors a prepared mind" indicates, chance discovery is possible if the context information brought by humans meets the information extracted from a data set. That is why information visualization is another important task for computer systems in chance discovery process. Information visualization systems display the collected data with a structure so that a user can easily grasp the important characteristics of the data set, such as the relationship among objects and trends in the domain of interest. Compared with scientific visualization systems, which handle huge but well-organized data set, their target data set is usually ill-organized and has a variety of potential structure. Therefore, not only visualization itself but also giving the data appropriate structure is important for information visualization. A chance is not common for everyone, but depends on the context in which a person tries to make decisions. That means information visualization systems will be effective if they can display the data set with the structure that matches the person's context.

2.2 KeyGraph

Concerning the important role of information visualization, a variety of information visualization systems have been designed for chance discovery process [4, 5, 6, 7], among which one of the most famous systems is KeyGraph [4]. This section briefly describes the graph generated by KeyGraph. The detailed description such as how the KeyGraph processes an original data set is found in [2].

Fig. 1 shows the example graph generated by KeyGraph, which consists of the following objects.

- **Black nodes** indicate the items frequently occurred in a data set (the word arranged close to a node refers to its content.).
- **White nodes** indicate the items not occurred so frequently in a data set.
- **Double-circled nodes** indicate the items that can be considered as important keywords.
- **Links** indicate that the connected item pair co-occurs frequently in a data set. A solid line is used for forming an island as mentioned below, while a dotted line is used for connecting islands.

There are also composite objects that are very important for grasping what a graph shows.

- **An island** is defined as the connected component of black nodes with solid lines. Although a single black node can be viewed as an island, this paper excludes such islands. In Fig.1, the sets of keywords, {"Fruit", "Meat", "Milk", "Vegetable", "Fish"}, {"Instant-food", "Snack", "Toy"}, and {"Cigarette", "Magazine", "Baby-diaper", "Beer"} form islands, respectively.
- **A bridge** is defined as the dotted line that connects between islands or nodes.

The islands can be viewed as the underlying common contexts, because they are formed by the set of items co-occurred frequently in the data set. For example, the island@in the left part in Fig. 1 refers to daily food. On the other hand, bridges are important in the sense that they connect two common contexts with new context, which is brought by the items that are not frequently occurred. While the common contexts represented by islands are widely known, the contexts represented by bridges are not so popular at this moment, which would lead to a chance.

2.3 Smart Data: Scenario to Data Mapping

The typical usage of KeyGraph in chance discovery process is that a user draws up a scenario from what they can read from a generated graph. Although

Cigarette, Magazine, Beer.
Beer, Appetizer.
Beer, Appetizer, Cigarette, Magazine.
Baby-diaper, Cigarette, Toy.
Magazine, Baby-diaper, Toy, Snack.
Vegetable, Meat, Fruits, Milk, Fish.
Toy, Snack, Instant-food.
Beer, Baby-diaper.
Vegetable, Meat, Fish.
Cigarette, Lighter.
Toy, Baby-diaper.
Homely-dishes, Milk, Instant-food.
Cigarette, Magazine, Beer, Baby-diaper.
Snack, Instant-food, Milk.
Cigarette, Magazine, Lighter, Fish.
Vegetable, Meat, Fish, Milk.
Milk, Fruits.
Snack, Beer, Fruits.
Beer, Appetizer, Fish.
Vegetable, Fish.
Fruits, Milk, Meat.
Instant-food, Beer, Homely-dishes.
Toy, Snacks, Instant-food.
Homely-dishes, Beer, Appetizer.

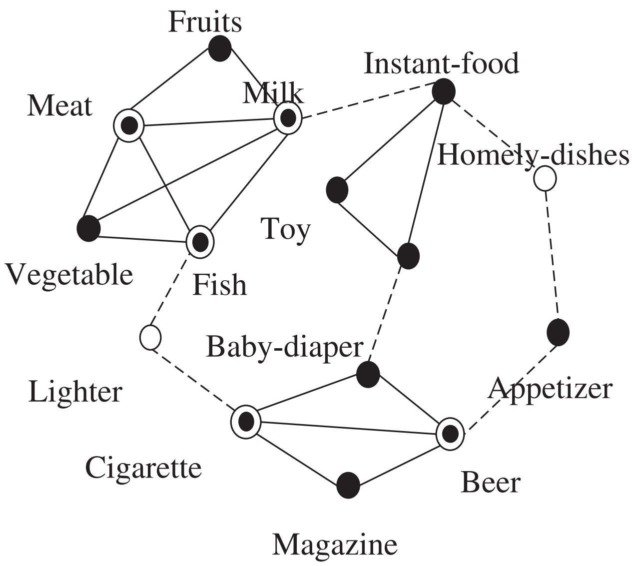

Fig. 1. Example data set and KeyGraph.

KeyGraph is one of the successful information visualization systems designed for chance discovery process, it should be noted that users have possibilities to misread the graph generated by KeyGraph with the following problems.

- A user tends to estimate the relationships between nodes based on their distance on the graph.
- Various graphs can be generated from a single data set.

As for the former problem, KeyGraph displays the relationship between nodes with links, and the distance between nodes can be determined differently from system to system. Some systems determine the distance among nodes based on their similarity as do typical information visualization systems [5, 7], while other systems determine the distance just in terms of arrangement. Therefore, there is a possibility that a user finds a "phantom" island based on the spatial proximity of keywords. Although a user who gets familiar with using KeyGraph could hardly make such mistakes, this problem becomes serious when a large number of nodes exist on a graph.

The latter problem is brought by the interactive facility the KeyGraph has. That is, users can generate preferred graphs by adjusting several parameters, such as the number of black nodes, solid links, and bridges. This facility is very useful for a data set to be visualized in suitable manners for the user's purpose, but different scenarios might be generated from each graph, even if these graphs are generated from the same data set. Although it is preferable in the context of chance discovery that each person generates different scenario from the same data set, too much variety of scenarios might cause a problem.

To solve these problems, this paper proposes to find the data referred to in the scenario and annotate those in the original data set. In other words, this approach finds the mapping from scenario to data. Finding the data that are referred to in the scenario lets users validate their scenarios. That is, users can examine whether the island they found is a phantom or not, as noted in the former problem, by looking into the corresponding data. Comparison between the data annotated with a scenario and those annotated with another scenario in the same data set is also helpful for solving the latter problem. As a result, the following benefits are expected.

1. Scenario comparison between different users can be possible. A scenario is written in natural language, which makes it difficult to compare a scenario with another one. On the other hand, the comparison on the basis of annotated data can be performed objectively, which could make the group discussion with KeyGraph more fruitful.
2. The annotated data can be extracted and used for generating a new graph, which focuses on the specific part of the original data set. As the chance discovery process is generally regarded as the double-helical model [3], which involves the repeated interaction between humans and computer systems, the graph generated from specific part of the data set will help users go into the further level of analysis.

It is interesting that computer processing has been moved from procedure-oriented approach, through object-oriented one, to data-oriented (i.e. application-independent) one just like the Semantic Web [1]. The data-oriented approach is often referred to as the "smart data" approach, which makes data smart. The proposed approach also goes along with the trend.

3 Scenario to Data Mapping Algorithm

3.1 Outline of Mapping Algorithm

This section proposes the algorithm for mapping from a scenario to an original data set. Fig. 2 shows the flow of the algorithm along with chance discovery process. The algorithm consists of 3 steps: The "(1) Graph analysis" step extracts a set of keywords (K_{all}), bridges (B_{all}), and islands (SL_M) from the graph data file, which is the output of KeyGraph. The "(2) Scenario analysis" step analyzes the text in the scenario and obtains a set of bridges (B_I) and islands (SL_I), which are of interest for the author of the scenario. Finally, in the "(3) Data annotation" step, the obtained bridges and islands are translated into logical expressions, which are used to retrieve and annotate the corresponding data in the original data set.

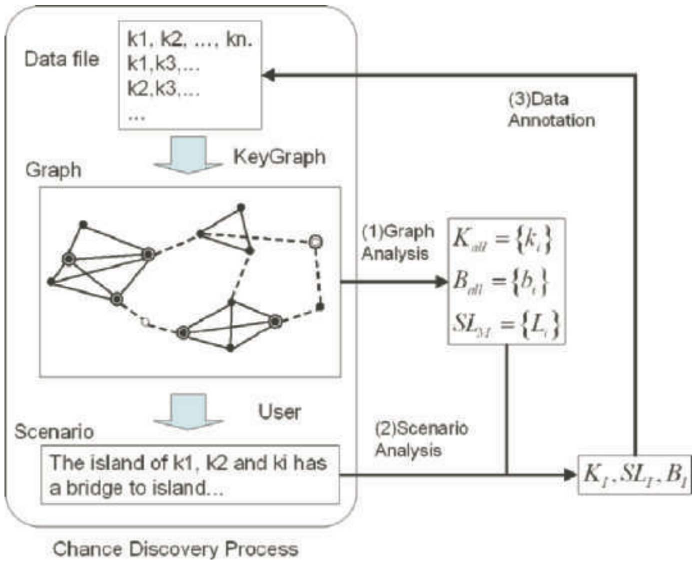

Fig. 2. Outline of mapping algorithm

3.2 Graph Analysis

This step extracts the set of keywords, bridges, and islands from the graph with the following procedures.

1. Extract a set of keywords that are appeared on the graph. The keyword k_i has two attributes, a word w_i and the node type t_i.

$$K_{all} = \{k_i(w_i, t_i)\}, t_i \in \{black, white\}. \quad (1)$$

2. Extract a set of links that are appeared on the graph. The link b_i is represented as a set of two keywords k_f and k_t, which are its endpoints.

$$B_{all} = \{b_i\}, b_i = \{k_f, k_t\}, k_f, k_t \in K_{all}. \quad (2)$$

3. Obtain a set of islands found on the graph. An island is mathematically defined as a connected component with solid lines, and represented by a set of keywords within the island.

$$SL_M = \{L_i\}, L_i = \{k_j \in K_{all}\}. \quad (3)$$

3.3 Scenario Analysis

This step finally obtains the set of bridges and islands, which are referred to by the user in his / her scenario.

1. Extract the set of keywords appeared in the scenario, $K_S \subseteq K_{all}$.
2. Obtain the set of optional islands (SL_U), which are defined by the user in the scenario. Since one node can belong to only one island, exclude the island from SL_M if it overlaps the island in SL_U.

$$\text{for } {}^{\forall}L_i \in SL_U, \quad \text{if } {}^{\exists}L_i \in SL_M, L_i \cap L_j \neq \phi, \text{then } SL_M \rightarrow SL_M - \{L_j\}. \quad (4)$$

3. Obtain the set of the islands which is referred to in the scenario,$SL_S \subseteq SL_M$. It is assumed that an island L_j is referred to, if one or more keywords in the island co-occur with the term denoting island, such as "island", "cluster" and "group", in at least one sentence in the scenario. The set of islands, in which the user is interested, can be obtained by extending the referred island set with user-defined island set.

$$SL_I = SL_S \cup SL_U \quad (5)$$

4. Obtain the set of the nodes (K_A) which are valid in the scenario. The K_A can be obtained by extending K_S with the nodes which belongs to SL_I.

$$K_A = K_S \cup \{k_i | {}^{\exists}L_j \in SL_I, s.t.k_i \in L_j\}. \quad (6)$$

5. Obtain the set of the bridges (B_A), which are valid in the scenario. The B_A can be obtained by excluding the bridges inside SL_I from those which exist among K_A.

$$B_A = \{b_n | b_n \subset K_A\} - \{b_m | {}^{\exists}L_i \in SL_I, b_m \subset L_i\}. \quad (7)$$

6. Obtain the set of the bridges (B_I), in which the user is interested, by applying the following steps to each sentence in the scenario.
   (i) If the sentence refers to only one node (k_I) or one island (L_k), which co-occurs with the term denoting bridge, such as "bridge", "link" and "connection", then add the set of bridges which meet the following requirements to B_I.
   - ${}^{\forall}b_n \in B_A, k_i \in b_n \rightarrow b_n \in B_I$. (node)
   - ${}^{\forall}b_n \in B_A, b_n \cap L_k \neq \phi \rightarrow b_n \in B_I$. (island)

   (ii) Otherwise, add the set of bridges which meet the following requirements to B_I. The K_i indicates the set of keywords which occur in the ith sentence (i.e. the sentence in process).
   ${}^{\forall}k_i \in K_i, \{b_n | b_n \in B_A, k_i \in b_n, b_n \subseteq K_i\} \subseteq B_I$.
7. When a sentence refers to the pair of islands (L_m, L_n), which has no bridges extracted in step 6-(ii), add all the bridges existing between those islands to B_i.

$$ {}^{\forall}b_i \in B_A, (b_i \cap L_m \neq \phi) \vee (b_i \cap L_n \neq \phi) \rightarrow b_i \in B_I. \quad (8)$$

8. As a white node often plays an important role as a relay of bridges, extend the set of bridges B_I in the following way.

$$\text{for } {}^{\forall}b_i \in B_I, \text{if } {}^{\exists}k_i \in b_i, s.t.\ t_i = white,$$
$$\text{then } {}^{\forall}b_i \in B_A, k_i \in b_i \rightarrow b_i \in B_I.$$

3.4 Data Annotation

Finally, the obtained bridges (B_I) and islands (SL_I) are translated into the logical expressions, by which the baskets to be annotated are extracted from the original data set. For an island L_i in SL_I, the basket containing 2 or more keywords that belong to L_i is extracted and annotated. For a bridge b_i in B_I, the basket containing both of its keywords (endpoints) is extracted and annotated. Whether a basket corresponds to a bridge or an island is identified with "type" attribute value of the tag. The example of the annotated data is shown in Fig. 3, of which the original data set is shown in Fig. 1.

4 Experiments on Data Annotation and Its Application to Chance Discovery Process Support

4.1 Purpose of Experiments

This section shows an availability of the proposed method in Chance Discovery process through experiments on the analysis of headlines of newspaper stories. As noted in Sec. 2.3, the following benefits are expected by annotating on original data set with the proposed method.

1. It becomes possible to compare scenarios objectively by referring to the original data set.
2. It becomes easy to focus on the important data subset.

In order to prove the first benefit, the result of scenario similarity calculation based on annotated data is compared with that based on VSM[8]. Furthermore, scenarios generated from different KeyGraphs are compared by using annotated data. As for the second benefit, we show how hidden relations could be found from new KeyGraph, which is generated with a data subset.

4.2 Experimental Settings

The original data set for the experiments consists of the headlines of newspaper stories about "Livedoor vs. Fuji TV" issue, which were collected from Japanese newspaper "Nihon Keizai Shinbun" from Jan 12, 2005 to June 26, 2005. The number of articles is 214 and each headline corresponds to a basket.

<s01 author="A" type="island">Cigarette,Magazine,Beer. </s01>

<s01 author="A" type="bridge">Beer,Appetizer.</s01>

<s01 author="A" type="island""bridge">Beer,Appetizer,Cigarette,Magazine. </s01>

<s01 author="A" type="island""bridge">Baby-diaper,Cigarette,Toy. </s01>

<s01 author="A" type="island""bridge">Magazine,Baby-diaper,Toy,Snack. </s01>

Vegetable,Meat,Fruits,Milk,Fish.

<s01 author="A" type="bridge">Toy,Snack,Instant-food. </s01>

<s01 author="A" type="island">Beer,Baby-diaper. </s01>

Vegetable,Meat,Fish.

Cigarette,Lighter.

<s01 author="A" type="bridge">Toy,Baby-diaper. </s01>

<s01 author="A" type="bridge">Homely-dishes,Milk,Instant-food. </s01>

<s01 author="A" type="island">Cigarette,Magazine,Beer,Baby-diaper. </s01>

<s01 author="A" type="bridge">Snack,Instant-food,Milk. </s01>

<s01 author="A" type="island">Cigarette,Magazine,Lighter,Fish. </s01>

Vegetable,Meat,Fish,Milk.

Milk,Fruits.

Snack,Beer,Fruits.

<s01 author="A" type="bridge">Beer,Appetizer,Fish. </s01>

Vegetable,Fish.

Fruits,Milk,Meat.

<s01 author="A" type="bridge">Instant-food,Beer,Homely-dishes. </s01>

<s01 author="A" type="bridge">Toy,Snack,Instant-food. </s01>

<s01 author="A" type="bridge">Homely-dishes,Beer,Appetizer. </s01>

Fig. 3. Annotation results of original data set in Fig. 1

In the experiments, newspaper headlines and scenarios are written in Japanese and translated into English in this paper. A basket consists of keywords in a headline, which is generated with the function of Polaris [8] and with manual correction in terms of fluctuation of description.

Two KeyGraphs (Fig. 4 and 5) are generated using Polaris, which is one of the effective tools for supporting chance discovery process. In Polaris, users can generate preferred graphs by adjusting several parameters, and analyze them interactively. In the experiments, the KeyGraphs are generated by adjusting the parameters so that the KeyGraph A (Fig. 4) can contain several small islands, and the KeyGraph B (Fig. 5) can contain a few big islands. From these KeyGraphs, four subjects generate four scenarios such as follows. In the

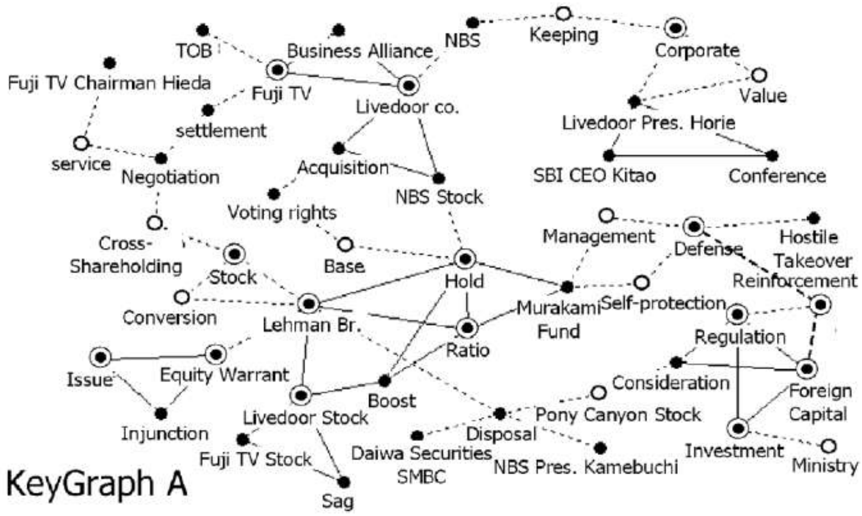

Fig. 4. KeyGraph A

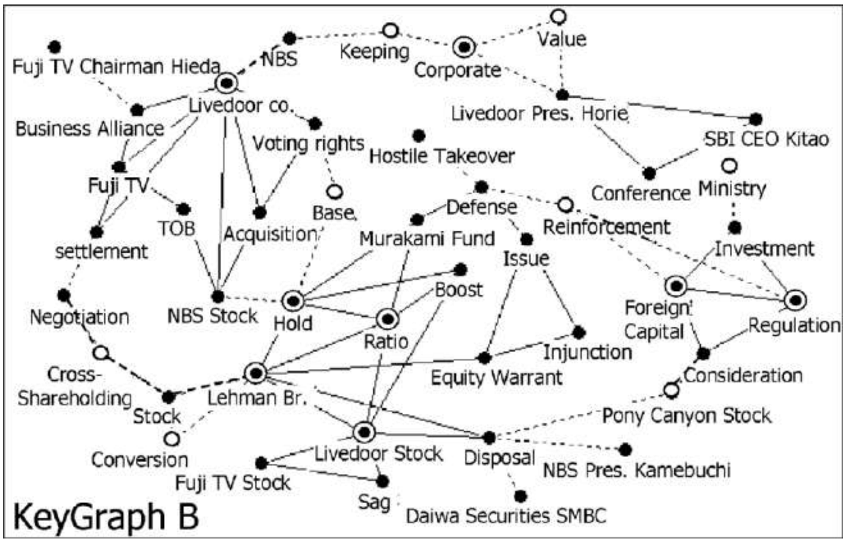

Fig. 5. KeyGraph B

scenario, the Keywords on the graph are underlined, and the island and bridge terms are written in italics.

- Scenario ID: s01 (from KeyGraph A)
  The *island* containing "Livedoor co.", "Fuji TV", etc. shows the surface of this problem. On the other hand, the *island* containing "Lehman Br." and

its *connection* from "Murakami Fund" through "Management", "Self-protection", "Defense" and "Reinforcement" to the *island* containing "Foreign Capital" and "Regulation" might show the hidden essence of this incident.

- Scenario ID: s02 (from KeyGraph A)
  There are two *connections* between the *island* containing "Lehman Br." and "Murakami Fund", which shows price movement of stocks, and that containing "Foreign Capital" and "Regulation"; one is through "Management", "Self-protection", "Defense", and "Reinforcement", which concerns management right protection, and another is through "Disposal" and "Pony Canyon stock", which concerns Scorched-earth defense.
- Scenario ID: s03 (from KeyGraph A)
  The *island* containing "Equity Warrant" and that containing "Livedoor Stock", "Hold" and "Ratio" show movements of "tools" in the capitalism, and this is surface and phenomenon people can see. The *island* of "Fuji TV", "Livedoor co." and "NBS" can be interpreted as a group from the viewpoint of "service". The *island* containing "Regulation", "Investment" and "Foreign Capital" shows this problem has happened in the particular field, broadcasting.
- Scenario ID: s04 (from KeyGraph B)
  Concerning the acquisition of "NBS Stock" by "Livedoor co." and "Fuji TV", "Ministry" will consider defense against "Hostile Takeover" by reinforcing regulations about transactions such as the regulations for "Investment" and "Foreign Capital", and injunction against "Equity Warrant" issue. As a result, the conversion of strategy regarding stock will lead "Fuji TV" and "Livedoor co." to settlement through negotiation.

4.3 Experimental Results of Annotated Data Utilization

Scenario Comparison

As the first benefits of data annotation, it becomes easy to compare scenarios objectively. The similarities between scenarios can be defined by using the Jaccard coefficient (Eq. (9)). In Eq. (9), $BL_I(BB_I)$ means the set of backsets annotated by the tags, of which the type attribute is island (bridge) and the scenario ID is i. That is, Eq. (9) calculates similarity between scenarios regardless of difference between island and bridge.

$$Sim(A, i, j) = \frac{(BL_i \cup BB_i) \cap (BL_j \cup BB_j)}{BL_i \cup BB_i \cup BL_j \cup BB_j} \tag{9}$$

The similarities between the four scenarios in Sec 4.2 are shown in Table 1.The similarities calculated by Vector Space Model (VSM) [9], are shown in Table 2 for comparison purpose. In VSM, the keywords on the KeyGraph are used as index terms, and each weight is calculated by using TFIDF

Table 1. Scenario similarity based on data annotation

ID	01	02	03	04
01	1.0	0.35	**0.76**	**0.52**
02	-	1.0	0.25	0.12
03	-	-	1.0	**0.6**
04	-	-	-	1.0

Table 2. Scenario similarity based on VSM

ID	01	02	03	04
01	1.0	**0.75**	0.27	0.43
02	-	1.0	0.10	0.18
03	-	-	1.0	0.41
04	-	-	-	1.0

[10]. The similarity between scenarios is defined by the inner product between corresponding vectors.

Although the values cannot be compared directly between the tables, the following difference can be seen between those methods; the similarity among s01, s03 and s04 are higher than others when Eq. (9) is used, while the similarity between s01 and s02 is higher than others when VSM is used. The difference is caused by the following reasons.

- The VSM uses superficial features such as the keywords appeared in a scenario.
- The similarity calculation with Eq. (9) is based on islands and bridges that are referred to in a scenario.

In order to illustrate this, we analyze the relationship between s01 and s03. It can be seen from the scenarios and KeyGraph A (Fig. 4) that both scenarios mention the following three islands in common.

- L_1 = {“Fuji TV”, “Livedoor co.”, “Business Alliance”, “Acquisition”, “NBS Stock”}.
- L_2 = {“Lehman Br.”, “Murakami Fund”, “Hold”, “Ratio”, “Livedoor Stock”, “Boost”, “Fuji TV Stock”, “Sag”}.
- L_3 = {“Regulation”, “Investment”, “Consideration”, “Foreign Capital”}.

The L_1 and L_3 are referred to with same keywords (L_1:“Livedoor co.” and “Fuji TV”, L_3: “Regulation” and “Foreign Capital”) in the both scenarios. However, L_2 is referred to with deferent keywords; “Lehman Br.” and “Murakami Fund” are used in s01, while “Livedoor Stock”, “Hold” and “Ratio” are used in s03. Therefore, VSM cannot consider the commonality between s01 and s03 in terms of L_2. On the other hand, the similarity calculation based

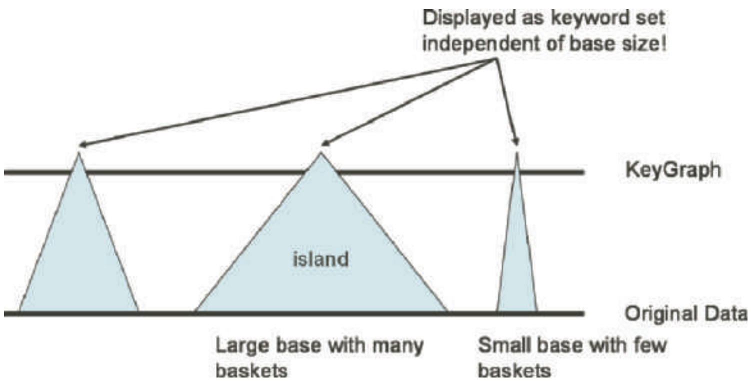

Fig. 6. Difference in scenario comparison between data annotation-based method and VSM

on data annotation considers all baskets relating with L_2, which contributes to reflect actual relationship between the scenarios.

In the case of s01 and s02, s02 does no refer to L_1. Because both scenarios refer to L_2 and L_3 with the same keywords, high similarity is lead with VSM. But the topic represented by L_1 is, "Acquisition of NBS Stock by Livedoor co., Fuji TV and its Business Alliance", which is one of the main topics in the data set of this experiment. That is, the author of s02 (without referring to L_1) interprets the issues of the data set differently from the author of s01, and the similarity between both scenarios should be low. On the other hand, as main topic tends to be mentioned in many headlines, the corresponding island consists of many baskets. That makes the similarity between s01 and s02 lower than that of VSM.

The difference between data annotation-based scenario comparison and VSM-based comparison is illustrated in Fig. 6. As described in Sec. 2.2, an island in a KeyGraph is formed by a number of corresponding baskets in an original data. However, once keywords have been selected as nodes on a KeyGraph, a user can discriminate them only as white or black nodes. Although the size of base, i.e. the number of corresponding baskets, is different from node to node, as shown in Fig. 6, a user cannot recognize such differences on a KeyGraph. Applying VSM to scenario comparison would correspond to the situation when a user compares scenarios based on only scenarios and KeyGraphs. On the other hand, comparing scenarios based on the annotated original data can consider the bases of islands, which are hidden behind the KeyGraph. Of course, as both methods compare scenarios with different kinds of features, a user can use both of them optionally. However, the annotation-based approach is expected to be more useful from the viewpoint of chance discovery, in the sense that it can find the similarity between scenarios that cannot be reflected on a KeyGraph.

Furthermore, by using the annotated data, the comparison of scenarios generated from different graphs becomes possible. For example, although s03 and s04 are generated from different graphs, their similarity is very high based on the annotated data. We assume that although the authors of these scenarios focus on the similar topics, the same topics might be represented in different ways between KeyGraph A (Fig. 4) and KeyGraph B (Fig. 5), which would make authors interpret the issue differently from each other. To examine the difference, we will extract the baskets which are annotated only with s04. The corresponding headlines are as follows.

- FSA moves to reinforce **regulations** against **hostile takeover** rapidly.
- NAB organizes new institution in the counsel about hedges against **hostile takeover**.
- Murakami Fund pres. said "**regulations** against **hostile takeover** are self-protection of executives."
- Fuji TV has increased authorized stock 1.5 times as@hedges against **hostile takeover**.

In the headlines, the keywords "regulation" and "hostile takeover" often appear, which shows the author of s04 mentions the connection from "regulation" to "hostile takeover" in KeyGraph B. From these headlines, author of s03 would notice the new way of interpretation: "regulation" is related to not only "Foreign Capital" and "Investment", but also to "Hostile takeover."

In other words, an author would notice new viewpoints of the same topics by comparing his/her scenario with that generated from different graph by using the annotated data.

Extraction of Data Subset

As the second benefits of data annotation, it becomes easy to focus on the important data subset.

For instance, we will focus on s01. The s01 focuses on the connection from L_2 to L_3, and also mentions L_1. We generate a data subset by extracting only the baskets annotated by s01, and the corresponding KeyGraph as shown in Fig. 7.

In KeyGraph A (Fig. 4), there is no bridge between L_2 and L_3. On the other hand, in this KeyGraph (Fig. 7), the Keyword "TOB" (take over bid) appears as the center of the bridge between them. From this, we might discover new opinion like this, "the TOB system is also one of the big factors that connects the surface of the issue (L_2) and its result (L_3)."

The extraction of data subset by annotated data and its re-visualization would help discover the hidden relations between nodes or islands, which are important for generating new scenario. This process is also important for supporting the double-helical model [3] in chance discovery process.

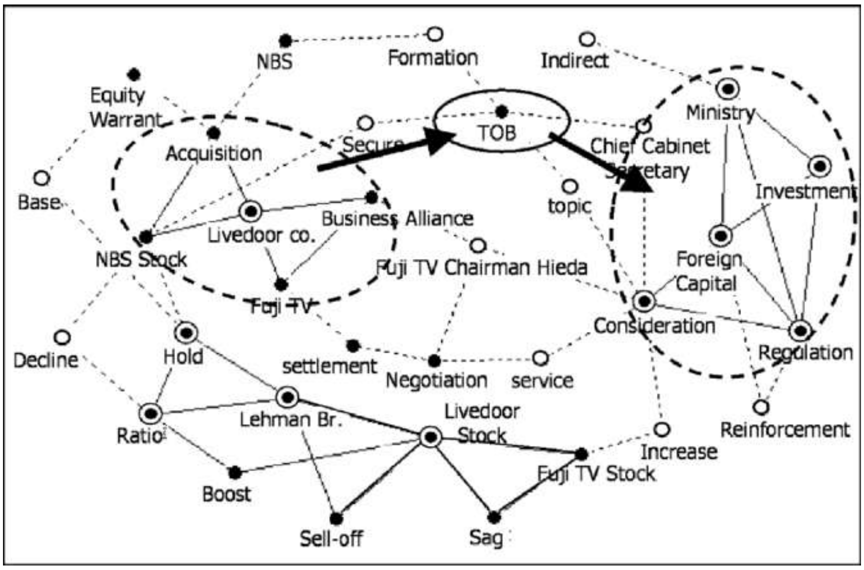

Fig. 7. KeyGraph generated from data subset

5 Conclusions

The mapping method between a graph generated by KeyGraph and a scenario is proposed for supporting chance discovery process. The mapping found by the algorithm is translated into logical expressions, which are used for extracting the data referred to in the scenario and annotating those in the original data set. Annotated data by proposed method can be used for the comparison of scenarios as well as the extraction of data subset for further analysis. The experimental result in terms of scenario similarity calculation based on the annotated data set shows the availability of the proposed method in chance discovery process. It also shows the graph generated from the data subset, which is extracted based on the annotated data, can support the discovery of the hidden relations and new scenario generation. Future works include the development of KeyGraph-based BBS system equipped with the data annotation engine.

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Smart Discussion Environment on a Bulletin Board System

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1 Introduction

It is important for a collaborative community to decide its next action. The leader of a collaborative community must choose an action that increases rewards and reduces risks. When a leader cannot make this decision, action will be determined through community member discussion. However, this decision cannot be made in blind discussions, so systematic discussion is necessary to choose effective action in a limited time. In addition, the repetition of divergence and convergence in the discussion according to members' common knowledge and background will lead to that effective conclusions.

Four key points must be considered in solving large problems by a discussion-based approach:

1. Management of discussion structure
2. Preservation of discussion coherence
3. Support for discussion divergence
4. Support for discussion convergence

The first point is management of discussion structure. For large problems, solutions are not achieved by short discussions but by problem divisions and their integration. Therefore, discussion members should understand how the problem is divided and where they should place priority in their discussion.

The second point is preservation of discussion coherence. Rewarding discussion must be clear in its goal and discussion topic. Along these lines, even if the goal is clear, no solution can be obtained without the members' conscious deliberation. There is no point to the discussion if its conclusion does not achieve the goal or reaches a different result.

The third point is support for discussion divergence. To get a good solution, many candidates should be enumerated before beginning to eliminate them. Enumeration should be done not by making judgement but by finding the seeds of solutions. As a problem becomes larger, wide-ranging discussion is

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needed to reach well-considered conclusions. In other words, to mine a deeper vertical hole, a larger horizontal space is needed. For such discussion divergence, members should have various kinds of knowledge and ideas related to the topic of the discussion.

The fourth point is support for discussion convergence. After the enumeration of ideas, notions should be formed regarding the shape of the problem. Scattered toys should be picked up before going to bed. Discussion members should find common characteristics and elements among the candidates in order to create solutions that capture the essence of the problem. Smart insights and logical thinking ability are clearly needed to achieve this.

A discussion environment that could address each of these four points would greatly help to reduce discussion time, concentrate discussion, and achieve great results. Therefore, such a discussion support environment is applied to a bulletin board system (BBS) on the Internet. The main advantage and disadvantage of a BBS are as follows.

- Advantage: does not need a common schedule and site
- Disadvantage: difficult to grasp discussion structure and progress

Essentially, a BBS on the Internet is designed for discussion members who cannot match their schedules and are in dispersed locations. They can write a comment whenever they are in front of their PC. However, it is difficult for them to comprehend how the discussion has been proceeding and how much the discussion has progressed. Furthermore, members have difficulty writing adequate comments before they have once again become abreast of the discussion's status by reading all of the one-dimensionally written comments.

An adequate comment can be contributed only with knowledge of the entire discussion's progress, the current discussion theme, and the kind of desired comment (divergent or convergent). Therefore, these types of information should be displayed in the BBS interface to encourage participation in the discussion. In this chapter, a discussion framework incorporating these four points is described. A model of discussion division and integration, discussion procedure, and criteria for each written comment are introduced. As a result, discussion members can grasp the status of a discussion and easily write comments.

A bulletin board system (BBS) framework proposed by me supports discussion divergence and convergence for deciding a series of actions to be undertaken. This BBS framework provides an environment in which the remote community members can participate in systematic discussions. In this framework, as the scenario must be stream-like, a sub-story model that supposes consecutive appearances of the same words is incorporated.

Rather than interpreting previous discussions, this study aims to smoothly control current and necessary discussions. That is, the system grasps each state of the discussion, indicates the type of opinion, and supplies environments for constructive discussions.

In the rest of this chapter, backgrounds are described in section 2. A substory model incorporated into a BBS framework is described in section 3 and a BBS framework in section 4. Evaluation criteria for each comment in BBS are determined in section 5. Experimental results are shown in section 6, and section 7 concludes this chapter.

2 Background

There are many types of Internet online communities, which can be mainly categorized as follows [1]:

A. Topic-based
B. Problem solving
C. Product/service evaluation
D. Mutual user support
E. Friend-making or leisure
F. Club

In this chapter, I address a B type problem solving community in which each member discusses a problem to find a solution.

Many relational works have analyzed the co-occurrence of words in each user comment to automatically classify communities into the above six types [2] or to visualize the structure of mutual citations [3]. In this study, although co-occurrence is also incorporated, a suggestion system measures discussion streams not only by two comments but also by more than three comments in which consecutive words appear.

These studies are also utilized as techniques for chance discovery because analysis of human relationships and visualization of community conversation realize followings.

- Visualize information what we potentially understand
- Visualize information what we normally cannot see

That is, a chance discovery system visualizes information what we partially known so that we can reconfirm our ambiguous knowledge. As for the second point, a chance discovery system visualizes unknown information so that we can find new directions for logical thinking. Chance is not a sudden occurrence of an idea, but a logical expansion by confirmed information and original viewpoints.

Discussion environment described in this chapter is not only an environment, but also a chance discovery tool for inspiring users mind. Comment evaluation criteria described in section 5 visualize each comment status related to topics of BBS so that users can find a new or a desirable direction of discussion.

Since there is a lexical chain [4] in natural language processing, the system is regarded as the application of a lexical chain without a thesaurus. A topic extraction method [5] extracts relationships in a story with a Text-Tiling method. However, such a system cannot be applied to bulletin board systems that contain various comments by multiple members. In this study, the framework assumes multiple sub-topics, loosely related in comment streams.

To measure the relationship between segments in a document, a Vector Space Model [6] is generally used, where the angle between two vectors is the relationship. However, this is insufficient for estimating a document stream because the angle is defined in only two segments. In addition, although there is a sentence ordering system for summarization [7], my study examines continual document streams.

3 Sub-story model

A document contains a main topic, the author's primary subject, and sub-topics related to the main topic. I label the logical stream of these topics main story and sub-story, respectively. A sub-story model is then defined as the words that appear in consecutive segments as the topic of the sub-stories to create a document stream (Fig. 1).

Terms related to sub-story models are defined as follows:

- main topic: a topic related to a text mainly described in many segments
- sub-topic: a topic related to a text partly described in more than two segments
- main/sub story: a logical relationship related to a main/sub topic
- main/sub keyword: a word representing a main/sub topic
- main/sub topic sentence: a sentence strongly related to a main/sub topic

"Main" and "Sub" in Fig. 1 denote the main topic with main keywords and sub-topic with sub-keywords, respectively, and arrows indicate the story.

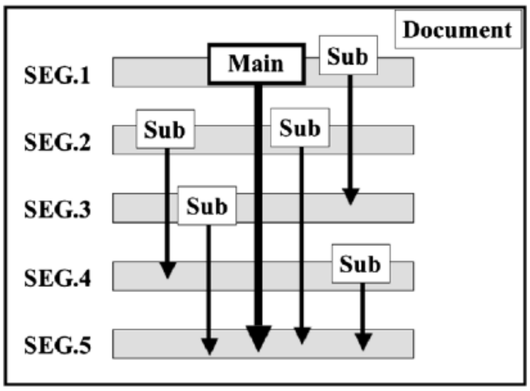

Fig. 1. Sub-story model

A unit for measuring a document stream is called a "segment." Segments are chapters, sections, or paragraphs that enable the system to observe the consecutive appearance of topic words.

3.1 Preliminary Experiments for Sub-story Model

To verify the sub-story model assumption described in section 3, preliminary experiments were executed to investigate how often words appear in texts in consecutive segments. The texts for these experiments were the 100 papers for the eighteenth annual conference of the Japanese Society of Artificial Intelligence. Each paper consists of four pages with about six segments. The papers were in Japanese, and nouns were extracted in advance by a Japanese morpheme analysys system [11].

Table 1 shows the tendency of nouns appearing in consecutive segments. These data are for 90 papers whose segment number (SEG) is from four to six, and the probability values denote the rate of words appearing in consecutive segment frequency (SF) segments over all words that appear in SF segments.

As a result, all real rates (Prob.) are larger than random values (Rnd.) [1] by more than 15%, so a word tends to appear in consecutive segments.

As second preliminary experimental results, Table 2 shows the appearing segment range (SR) for all parts of speech: nouns (Nn), verbs (Vb), adjectives (Adj), conjunctions (Con), adverbs only for nouns (Adn), adverbs (Adv), particle (Pc) auxiliary verbs (AV), and Random probabilities (Rn) in 45 texts consist of five segments. The rate of each part of speech for all words are shown in Table 3.

As a result, all parts of speech exceed the random values, so all words tend to appear in each text consecutively.

Table 1. Probability of a noun, whose SF equals N, appearing in N consecutive segments

SEG	SF	Noun	Prob.	Rnd.
4	2	989	74%	50%
5	2	2940	58%	40%
6	2	1815	49%	33%
4	3	440	73%	50%
5	3	1391	47%	30%
6	3	919	38%	20%
5	4	791	55%	40%
6	4	555	39%	20%
6	5	335	49%	33%

[1] In a four segments text, when a word's SF is two, 1-2, 2-3, 3-4 are consecutive appearing patterns, and 1-3, 2-4, 1-4 are not consecutive. If that word appear in random segments, 50% (= $3/(3+3)$) becomes the random value.

Table 2. Cumlative rates of appearing segment range (SR) of a word whose SF equals 2 by a part of speech (%)

SR	Nn	Vb	Adj	Co	Adn	Adv	Pc	AV	Rn
2	58	58	52	50	49	49	52	49	40
3	85	86	84	81	82	84	81	84	70
4	95	96	94	99	97	96	97	100	90
5	100	100	100	100	100	100	100	100	100
word	2940	546	104	128	39	108	286	49	

Table 3. Rate of part of speech for all words

part of speech	rate
nouns	69%
verbs	15%
particles	7%
others	9%

According to these preliminary experiments results, similar linguistic expressions are used continuously, and most words in a document tend to appear in a shorter range of segments independent of part of speech. In other words, the words appeared in consecutive segments as often possible. Especially, nouns and verbs are likely to appear continuously because they are used as subject and predicate in each sentence. On the contrary, the other repetition of parts of speech may be caused unconsciously because of writing habits.

3.2 Discussion control using a sub-story model

In this study, I apply this sub-story model by regarding a thread in a BBS as a document and a segment as a comment written by a community member. The word for the discussion topic becomes the main topic and main keywords, and the relational significant words of the main topic become sub-topics and sub-keywords. The system supplies implications of each comment status by regarding the consecutive appearing words as the appearance of the document stream.

4 Discussion Support Bulletin Board System

In this section, I describe a BBS system framework that supports discussion control by the sub-story model described in the previous section.

4.1 Definitions

First, terms and environments for the BBS framework are defined. A community consists of multiple members with a leader. BBS functions as an environment in which members discuss a topic established by the leader. In

BBS, members can create multiple threads and engage in discussion by writing comments in each thread. The words, the BBS, threads, and comments are defined as follows:

- BBS: a discussion environment for community members using the Internet; a set of threads.
- Thread: a blackboard system in which members can discuss the topic by writing comments; a set of comments.
- Comment: a member's written opinion.

The person who controls the discussion is not a system but a leader and a member of the community. The system clarifies the placement of each comment in the flow of the topical discussion and implies byway or unrelated comments and urges comments including necessary elements.

4.2 Discussion streams

The discussion procedure for problem solving from topic suggestion to a conclusion that has a solution is as follows:

[**Discussion Process**]

1. Create a thread of the main/sub-topic.
2. Divergence Phase: Discussion to diverge opinions and ideas.
   If a sub-topic is suggested,
   a) For the sub-topic, follow procedures 1 to 5.
   b) Embed its conclusion.
3. Change from divergence phase to convergence phase.
4. Convergence Phase: Discussion to converge the collected opinions.
5. Create conclusions for the main/sub-topic.

This procedure is similar to the relationship among main function and the sub-functions in computer programming, as shown in Fig. 2; each body of the thread develops, as in Fig. 3. The tree structure expresses problem occurrence and divisions. A large problem is divided into small problems recursively to solve more concrete problems and to accumulate the solutions.

The system also assumes that problem division in a thread is executed, as Fig. 3 When a member find that a problem is divided into more concrete

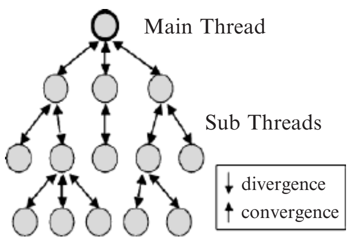

Fig. 2. Divergence and convergence of threads in BBS

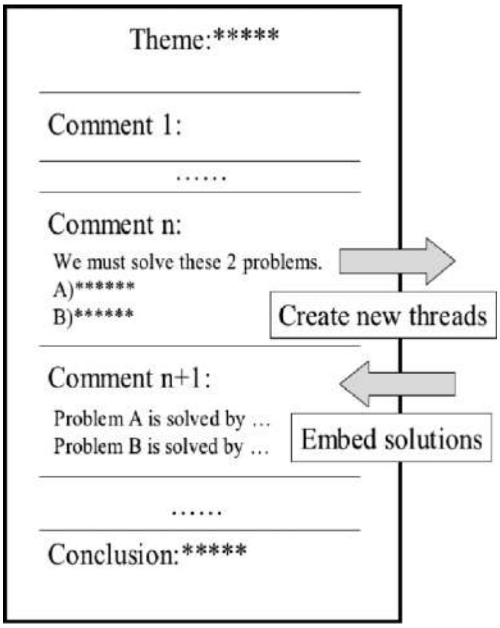

Fig. 3. Example description of a thread

problems, he/she creates a new sub-thread for each. Solutions are embedded after the problems are solved.

In the rest of this section, the procedure of this process is described.

Creation of a thread

A community leader establishes a main topic and creates a new thread for discussion. A community member creates a new thread by creating a sub-topic in the divergence phase. The following are the types of threads:

- Main: thread about main topic created by the leader of a community.
- Sub: thread about a sub-topic created by a member of the community.
- Byway: thread about a secondary additional topic that does not affect the solution of the main topic.

By creating a thread for each divided distinct topic, members can concentrate on discuss a topic and the system can grasp states of the thread.

Divergence Phase

Discussion is divided mainly into two phases: divergence and convergence. In the divergence phase, members hold discussions to collect opinions. The rate of divergence is simply measured by new words. However, if the topic spreads blindly, discussion will not converge. Therefore, the system supports discussion control in the range of the topic and supports the various opinions of members.

The divergence of the discussion is then calculated by counting the number of words in a thread related to the topic. When a new comment is written, the number of new words is counted as a value contributing to the divergence of the discussion (details are shown in section 5). If a new comment has many new words unrelated to the topic, this comment is treated as a byway topic, and the leader urges the member to make a new byway thread or to reduce the comment.

It is effective for members to provide some relational knowledge for new ideas and diverging discussion. For example, relational words and images, which frequently appear in Web pages including topic words, may be useful. Some systems such as information clustering [9] and image retrieval [10] will be combined as discussion support plug-in softwares in the future.

Creation of a sub-thread

In the divergence phase, if it is clear that conditions for solving the topic of the current thread exist, and if the members acknowledge that they are valid, a new sub-thread is created by the member who set those conditions.

Once a new sub-thread is created, the current thread is suspended because sub-thread solutions are necessary conditions of the current topic. The conclusions of sub-topics are obtained by the same procedure as the main topic. When provided by the sub-threads, these conclusions are embedded into the original suspended, which is reopened.

Transition from Divergence to Convergence Phase

After most opinions have been added to the thread, the discussion phase switches from divergence to convergence.

That is, if there was a discussion that exceeded the threshold, calculated by the number of relational keywords of the topic, the number of sub-threads, and the discussion time from when the thread was created, a transition is suggested to the member who created the thread. If the member agrees, the transition will be executed.

Convergence Phase

In the convergence phase, a new discussion is not needed, but discussion continues to converge opinions and already obtained conclusions. Therefore, the rate of new words is minimized by the suggestions of the system. In addition, to converge the sub-thread conclusions, new comments using multiple topics of sub-threads are recommended; sub-topics supplied by order of occurrence and comments, including adjacent topics, are recommended.

Transition from Convergence to Divergence Phase

The system is normally expected to switch the phases from divergence to convergence, although the opposite switch, from convergence to divergence, may occur in ordinary discussions. New ideas may occur after seeing the piled up entities as the result of discussion. However, if this switch is incorporated, discussion time will drastically increase, and discussions will never be converged for the largest problems. Therefore, this switch to divergence is not considered in usual occasions, but only when the community leader permits and a thread satisfies such restricted conditions as a new comment is judged creative or innovative.

Create topic conclusions

When the comments, including the oldest sub-topic, and all topics have appeared, the system urges the member who created the thread to create conclusions. After conclusions are declared, the thread is closed.

4.3 Conditions to Comments

Members write their opinions in the threads as comments. However, since it is hard to control discussions written in a free format, conditions are attached to the comments for discussion analysis based on the sub-story model. The system recommends that users write new comments including consecutive words, while the system examines each comment to ensure that it conforms to the topic and the discussion stream. The following conditions are highly recommended for each comment:

- Use the topic word in the thread.
- Use words already used in the same thread.
- Avoid pronouns.
- Use new relational words of the topic in the divergence phase.
- Use multiple words for sub-topics in the convergence phase.

These suggestions help users write comments for systematic discussions, such as retention of logical relationships, divergence and convergence. To write a comment along these conditions, concrete numerical criteria and comments evaluation criteria are calculated and displayed.

In addition, a brief suggestion to each comment is displayed such as follows:

- Please use topic words.
- GOOD/EXCELLENT for divergence.
- GOOD/EXCELLENT for convergence.
- GOOD/EXCELLENT incorporation.
- It seems a BYWAY/FLOOD.

"Incorporation" means that a member use unrelated words used in the former comments to incorporate into topic related words (details are described in the next section).

5 Comment Evaluation Criteria

In this section, eight comment evaluation criteria for discussion control are described. Six criteria are word evaluations used in each comment, and the other two are status evaluations in discussion streams. The criteria are as follows:

1. topic: relevance to the topic
2. flow: continuity related to the topic
3. new: new tips related to the topic
4. inc: incorporation to the topic
5. byway: continuity unrelated to the topic
6. flood: new tips unrelated to the topic

Criteria from 1 to 6, which are calculated by evaluating words in each comment, are mainly a relationship with the topic words. Finally, criteria for divergence and convergence are prepared by a combination of these six criteria.

a. div: divergence for discussion
b. conv: convergence for discussion

In the rest of this section, these criteria are defined precisely, and "words" mean nouns extracted from each comment. In the future, "words" can be replaced by a set of parts of speech or real words depending on BBS type or language.

5.1 Distance between words

For the definition of criteria, word distance that denotes the relevance between two words is defined. A corpus is not available because words relationships are depend on a topic and contexts.

First, the distance value in comment C between words w_i and w_j is calculated by Eq. (1):

$$distance(w_i, w_j, C) = |ia(w_i, C) - ia(w_j, C)|, \tag{1}$$

where $ia(W, C)$ is a function that gives the number of words between the top of comment C to the first appearance of word W. This distance assumes that a word should be defined at its first appearance as a opinion of the comment.

By using this distance in a comment, preliminary distance (*pre_distance*) between words W_1 and W_2 for n-th comment in a thread is defined as Eq. (2):

$$pre\_distance(W_1, W_2, C_n) = \min_{i=1...n} \{distance(W_1, W_2, C_i)\}. \quad (2)$$

This preliminary distance assumes that a member writes a comment referring to the former comments and learning relationship among words in the thread.

5.2 Word Labeling

Each word in each comment is labeled according to the role of each word. The definition of each label is as follows and Fig. 4 shows the relationship among them.

1. TOPIC: topic words
2. FLOW: already appeared words related to topic
3. NEW: new words related to topic
4. INC: incorporated words from unrelated into related ones
5. BYWAY: already appeared words unrelated to topic
6. FLOOD: new words unrelated to topic

Relevance threshold $dmax$ is defined as 10, which is the maximum distance from one of the topic words. Word W is related to the topic if and only if the distance between W and one of the topic words is smaller than $dmax$. This threshold is defined by preliminary experimental results where a meaningful sentence includes at least seven words [8]. A relational word should be included in three sentences: a sentence containing a topic word, the former, and the latter for the relationship. Therefore, 20 words are relational except a topic word, and the threshold distance is reduced by half.

New words will be labeled either NEW or FLOOD based on the distance from a topic word. For the secondly appeared words, based on the transition in Fig. 4, they are labeled FLOW if that word was initially labeled NEW. If a word was initially labeled FLOOD, that word is labeled BYWAY if its distance from a topic word is no less than $dmax$, it otherwise is labeled INC. A word is labeled unrelated to the topic as long as it appears far from topic words.

5.3 Topic relevance (topic)

Topic relevance of k-th comment C_k in the thread is given by Eq. (3) as the sum of the minimum distance to each topic word and its normalization, where n is the number of topic words and $dmax$ is the distance threshold defined in 5.2:

$$topic(C_k) = 1 - \frac{1}{n \times dmax} \sum_{i=1}^{n} d_i. \quad (3)$$

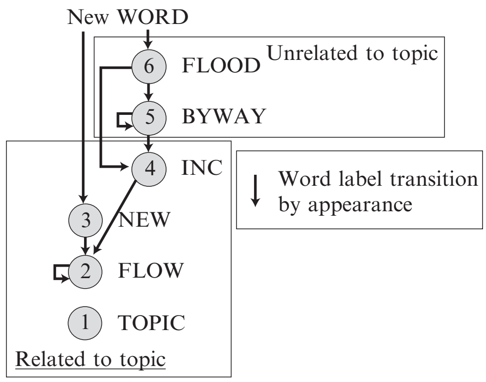

Fig. 4. Word's labels and its transitions

In addition, the minimum distance value from i-th topic word in k-th comment C_k is defined as Eq. (4):

$$d_i = \min\{dmax, \min_j\{pre\_distance(T_i, c_j, C_{k-1})\}\}. \tag{4}$$

That is, for each word $\{c_j\}$ in comment C_k, d_i is set to the minimum preliminary distance from each topic word $\{t_i\}$ in topic word set T until $(k-1)$-th comment. If d_i exceeds $dmax$, d_i is set to $dmax$.

As a result, topic relevance is one if a comment is the most related to the topic and is zero if a comment is the least related. This criterion evaluates the relevance to all topic words of the thread because all comments should be written along the established topic of a thread.

Even if a comment does not include any topic words, topic relational words such as labeled FLOW are counted into *topic*. Because of this calculation of secondary topic relationships, a comment should not always include topic words.

5.4 Topic continuity (flow)

Topic continuity of k-th comment C_k in the thread is given by Eq. (5) as the number of continuously used words labeled FLOW:

$$flow(C_k) = number(C_k, FLOW). \tag{5}$$

This criterion evaluates the contribution to creating a discussion stream by using words related to the topic of a thread. If a comment is written by many topical words used in former comments, $flow$ becomes large.

5.5 Topic novelty (new)

Topic novelty of k-th comment C_k in the thread is given by Eq. (6) as the number of new words labeled NEW:

$$new(C_k) = number(C_k, NEW). \tag{6}$$

This criterion evaluates the contribution to the provision of new tips related to the topic of a thread. If a comment includes new idea or information related to the topic, *new* becomes large.

5.6 Topical incorporation (inc)

Topical incorporation of k-th comment C_k in the thread is given by Eq. (7) as the number of incorporated words labeled INC:

$$inc(C_k) = number(C_k, INC). \tag{7}$$

This criterion evaluates the contribution to the incorporation of unrelated words used in the former comments. If a comment connects unrelated former comments with the topic, *inc* becomes large.

5.7 Unrelated continuity (byway)

Unrelated continuity of k-th comment C_k in the thread is given by Eq. (8) as the number of continuously used words labeled BYWAY:

$$byway(C_k) = number(C_k, BYWAY). \tag{8}$$

This criterion evaluates the disturbance to the discussion by the continuous use of unrelated words used in the former comments. If a comment succeeds unrelated former comments without connecting to the topic, *byway* becomes large.

5.8 Unrelated novelty (flood)

Unrelated novelty of k-th comment C_k in the thread is given by Eq. (9) as the number of new words labeled FLOOD:

$$flood(C_k) = number(C_k, FLOOD). \tag{9}$$

This criterion evaluates the disturbance to the discussion by providing new tips unrelated to the topic of a thread. If a comment includes new idea or information that does not seem to be related to the topic, *flood* becomes large.

5.9 Discussion divergence (div)

Discussion divergence of k-th comment C_k in the thread is given by Eq. (10) as the rate of new words above words variety, where *variety* is the kind of words in comment C_k:

$$div(C_k) = topic(C_k) \times \frac{new(C_k)}{variety(C_k)}. \tag{10}$$

This criterion is used for progress and promotion of discussion divergence related to the topic of a thread. If a comment includes new idea or information and is surely related to the topic, *div* becomes large. For discussion divergence, new relational tips are the most desirable.

5.10 Discussion convergence (conv)

Discussion convergence of k-th comment C_k in the thread is given by Eq. (11) as the divergence criterion, the rate of FLOW, INC, FLOOD, and BYWAY words above the number of words in the comment C_k as $Allnum(C_k)$.

$$\begin{aligned} &conv(C_k) = topic(C_k) \times \\ &\{1 - |div(C_k) - (1 - t)| \\ &-|\frac{flow(C_k) + inc(C_k)}{Allnum(C_k)} - t| \\ &-\frac{flood(C_k) + byway(C_k)}{Allnum(C_k)}\}. \end{aligned} \tag{11}$$

That is, discussion convergence consists of t % of FLOW+INC and $(1-t)$ % of divergence except FLOOD and BYWAY because convergent comments should have well-defined words in the former discussion and some new convergent knowledge. Currently, the rate of t is set to 0.85 by the experimental results in section 6. If *convergence* becomes negative, it is set to zero.

This criterion is used for the progress and promotion of discussion convergence related to the topic of a thread. If a comment includes new words representing whole discussion in the thread, *conv* becomes large.

5.11 Significance of comment criteria

By displaying these described comment criteria, a community leader can eliminate unnecessary comments and encourage members to write more adequate comments because such comment criteria are not visible in an ordinary BBS.

Table 4. Comment evaluation criteria for this chapter

COM	TOP	FLW+INC	NEW	BY+FLD	DIV	CONV
1	1.00	29	62	7	1.00	0.00
2	0.95	71	42	41	0.46	0.03
3	0.90	146	30	95	0.23	0.23
4	1.00	543	110	36	0.70	0.34
5	0.95	364	25	69	0.20	0.70
6	0.95	123	5	38	0.07	0.56
7	1.00	25	4	0	0.25	0.89

Each member can also do self-contemplation and eagerly to write comments to contribute to discussion progress if such comments are judged as BYWAY or FLOOD, despite their intention to contribute to the discussion.

In addition, all members can grasp how smoothly a discussion evolves because each comment position is obviously revealed. Therefore, members can have a wide vision to the discussion status, such as its stream and progress.

5.12 Numerical examples of comment criteria

Table. 4 shows numerical examples of all criteria described in this section. The sample text is the Japanese manuscript of this chapter, and each section corresponds to a comment.

In this table, sections 1 and 4 have high divergence values, and sections 7 and 5 have high convergence values. These results are intuitively understandable because a text expands topics in the initial section and concludes in the last section. In addition, since section 4 contains many definitions of the bulletin board system and section 5 gives concrete criteria for discussion divergence and convergence, those sections are interpreted as topic expansions and conclusions.

6 Experiments for discussion divergence and convergence

An ordinary paper consists of the following sections: introductions, related works, system, experiments, discussion, and conclusions. The introduction section is the most divergent and the conclusion is the most convergent. Therefore, I verify that the largest value of divergence and convergence are given to the first and the last sections, respectively, when words in a paper title are used as topic words. The texts used for these experiments are the 100 papers used in 3.1.

In addition, beginning sections in a paper tend to have the large value in the divergence, and end sections tend to have a large value in the convergence value. So, the following texts were prepared for comparison:

- TEXT-O: original papers
- TEXT-B: papers that exchanged the first and second sections
- TEXT-C: papers that exchanged the last and the next to last section.

Table 5 shows the averaged divergence and the averaged rates of the largest values in each paper for the first and the second segments. In TEXT-O, the rate of the first segment was 79%, which is larger than the second by 65%, though the values were almost the same in TEXT-B. Therefore, the divergence criteria captured that segment "Introduction" was divergent in the relation of each original paper topic.

Table 6 shows the averaged convergence and the averaged rates of the largest values in each paper for the last (L1) and the next to last (L2) segments. In TEXT-O, the rate of the last segment was 74%, which is larger than the next to last by 62%, and the next to last was the most in TEXT-C. Therefore, the convergence criteria captured that the segment "conclusions" was the most convergent in the relation of each original paper topic.

Finally, Fig. 5 shows the relationship between t-parameter and convergence in TEXT-O. Convergence should become large in the last segment but small

Table 5. Averaged divergence values and rates having best value in each paper for first and second segments

text	div-1 (best)	div-2 (best)	Difference
TEXT-O	0.67 (79%)	0.37 (14%)	0.30 (65%)
TEXT-B	0.49 (48%)	0.48 (41%)	0.01 (7%)

Table 6. Averaged convergence values and rates having best value in each paper

text	conv-L1 (best)	conv-L2 (best)	Difference
TEXT-O	0.53 (74%)	0.32 (12%)	0.21 (62%)
TEXT-C	0.36 (30%)	0.43 (53%)	-0.07 (-23%)

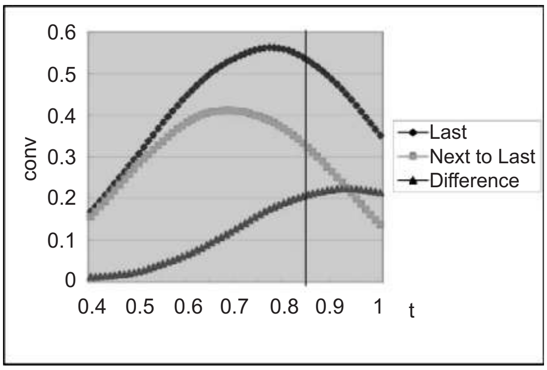

Fig. 5. Relationship between t-parameter and convergence in TEXT-O

in the next to last. Therefore, t-parameter was set to 0.85 for the difference to become large. As a result, a paper consists of 85% already appeared words and 15% new words for concluding summary and future directions.

7 Conclusion

In this chapter, a bulletin board system framework for discussion support using a sub-story model is introduced. To control the discussion stream of divergence and convergence, consecutive word appearance in a document stream model is applied. Criteria for divergence and convergence are evaluated by research papers as imitative discussion.

Such a smart discussion environment will be more necessary as information-technology grows. For application of the system, a community member should see each comment status and comprehend each comment role. A scenario to the desirable future will not created without cooperation among all members and their consciousness. Human-system collaboration give birth to original ideas and synergistic results.

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Prefiguring Ethical Chances: The Role of Moral Mediators

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Summary. First of all I will illustrate in this paper that some typical internal abductive processes are involved in *chance discovery* and *production* (for example through radical innovations) in science. Nevertheless, especially concrete manipulations of the external world constitute a fundamental passage in chance discovery: in science - for example - by a process of manipulative abduction it is possible to build prostheses (*epistemic mediators*) for human minds, by interacting with external objects and representations in a constructive way. In this manner it is possible to create implicit knowledge through doing and to produce various opportunity to find, for example, anomalies and fruitful new risky perspectives. This kind of embodied and unexpressed knowledge holds a key role in the subsequent processes of scientific comprehension and discovery but also in ethical thinking and in moral deliberation. Moral reasoning could be viewed as a form of "possible worlds" anticipation, a way of getting chances to shape the human world and act in it. It could be of help to prefigure risks, possibilities, and effects of human acting, and to promote or prevent a broad variety of guidelines. Creating ethics means creating the world and its directions, in front of different (real or abstract) situations and problems. In this way events and situations can be reinvented either as an opportunity or as a risk for new moral directions. The second part of the paper describes some of the "templates" of manipulative behavior which account for the most common cognitive and moral acting related to chance discovery and chance production.

1 Rational Acting in a Human Unsettled World

Morality could be defined, at the very last, as "the effort to guide one's conduct by reason - that is, to do what there are the best reasons for doing - while giving equal weight to the interests of each individual who will be affected by one's conduct: there are not privileged people" [1].

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Moral reasoning could be viewed as a form of "possible worlds" anticipation, a way of getting chances to shape the human world and act in it. It could be of help to prefigure risks, possibilities, and effects of human acting, and to promote or prevent a broad variety of guidelines. Hence, we need 1) to possess good and sound principles applicable to the various problems, able to give rise to arguments that can be offered for opposite moral views, and 2) appropriate ways of reasoning which permits us to apply the available reasons in the best way. "Creating ethics" means creating the world and its directions, in front of different (real or abstract) situations and problems. This process requires the adoption of skillful and creative ideas, in order to react in response of new previously unknown cases or in cases of moral conflict. In this way events and situations can be reinvented either as an opportunity or as a risk for new moral directions.

2 An Epistemological Framework

Living morally is the capacity to apply a kind of reasoning able to provide valuable moral knowledge and skillful templates which can explain behaviors, duties, and options, and to provide suitable deliberations. Moral deliberations relate to a sort of *selection* or *creation* of principles and to their application to concrete cases. We can both just select (or create, if we do not have any) moral principles and apply them to concrete cases or looking for the best ones among them according to some ethical meta-criteria. When we create new ethics, we provide new knowledge and new rules about problems and situations not yet clearly covered from the moral point of view. In this last case we certainly are in front of a particular case, but the problem is not only the one of ethically solving the case at hand by applying already available ethical concerns - indeed we lack a satisfactory moral knowledge to handle the puzzling situation. Instead we need to create something new, for example new good reasons first of all able to provide an acceptable intelligibility of the problem. In short, new chances have to be "extracted" and/or "produced" [2].

Sometimes, rather than the mere application of thinking, to reach a satisfactory moral deliberation it could be necessary to immediately act and manipulate objects and situations in the environment. This is also due to the fact that usually moral decisions are based on incomplete or inconsistent information. In logical terms we can say we are in front of non-monotonic inferences, which try to draw defeasible conclusions from incomplete information. The same situation occurs in the case of practical reasoning: ethical deliberations are always adopted on the basis of incomplete information.[1] To

[1] A logical system is monotonic if the function *Theo* that relates every set of wffs to the set of their theorems holds the following property: for every set of premises S and for every set of premises S', $S \subseteq S'$, implies $Theo(S') \subseteq Theo(S')$. Traditional deductive logics are always monotonic: intuitively, adding new premises (axioms)

clarify these problems it could be useful to consider an epistemological model already used to study the revolutionary transformations in science [8].

2.1 Theoretical and Manipulative Thinking

Science is one of the most explicitly constructed, abstract, and creative forms of human knowledge. The problem of scientific discovery and change has been central inside philosophy of science since the mid-1960s, when some critics challenged the traditional picture of conceptual change, offered by logical positivism, as a continuous and cumulative process justifiable by modern formal logic. Kuhn, by means of his perspective in terms of "paradigms", claimed that scientific change is assimilable to some sort of irrational and not analyzable *Gestalt-switch*, best understood as a conceptual *revolution* involving the overthrow and the replacement of the reigning concepts with others *incommensurable* (see [9]). In the twentieth century Reichenbachian and Popperian [10, 11] distinction between *logic of discovery* and *logic of justification*, and Kuhnian ideas about irrationality of conceptual change and paradigm shift [9] brought philosophers of science to the direct conclusion that a logic of discovery, and then a *rational* model of discovery, cannot exist.

This was coherent with a cataclysmic and irrational interpretation of the scientific enterprise, justified by the apparent dramatic and discontinuous nature of scientific change. Today researchers have by and large abandoned this attitude by concentrating on the concept of *abduction* pointed out by C.S. Peirce as a fundamental mechanism by which it is possible to account for the introduction of new explanatory hypotheses in science.

Abduction is the process of *inferring* certain facts and/or laws and hypotheses that render some sentences plausible, that *explain* or *discover* some (eventually new) phenomenon or observation; it is the process of reasoning in which explanatory hypotheses are formed and evaluated. There are two main epistemological meanings of the word abduction [8]: 1) abduction that only generates "plausible" hypotheses ("selective" or "creative") and 2) abduction considered as inference "to the best explanation", which also evaluates hypotheses. To illustrate from the field of medical knowledge, the discovery of a new disease and the manifestations it causes can be considered as the result of a creative abductive inference. Therefore, "creative" abduction deals with the whole field of the growth of scientific knowledge. This is irrelevant in medical diagnosis where instead the task is to "select" from an encyclopedia of pre-stored diagnostic entities.We can call both inferences ampliative, selective

will never invalidate old conclusions. In a nonmonotonic system, when axioms, or premises, increase, their theorems do not ([3, 4, 5]. Also in a great part of practical reasoning, when we add new data and information, we are compelled to abandon previously derived plausible/good moral reasons. On moral arguments that have a deductively valid or fallacious form (in the sense of classical logic) [6, pp. 33-44]. Recent research in the area of the so-called "practical reasoning", that relates to figuring out what to do, is illustrated in [7].

and creative, because in both cases the reasoning involved amplifies, or goes beyond, the information incorporated in the premises.

Theoretical abduction[2] certainly illustrates much of what is important in creative abductive reasoning, in humans and in computational programs, but fails to account for many cases of explanations occurring in science when the exploitation of environment is crucial. It fails to account for those cases in which there is a kind of "discovering through doing", cases in which new and still unexpressed information is codified by means of manipulations of some external objects (*epistemic mediators*). The concept of *manipulative abduction*[3] captures a large part of scientists thinking where the role of action is central, and where the features of this action are implicit and hard to be elicited: action can provide otherwise unavailable information that enables the agent to solve problems by starting and by performing a suitable abductive process of generation or selection of hypotheses.

Throughout his career it was C.S. Peirce that defended the thesis that, besides deduction and induction[4], there is a third mode of inference that constitutes the only method for really improving scientific knowledge, which he called *abduction*. Science improves and grows continuously, but this continuous enrichment cannot be due to deduction, nor to induction: deduction does not produce any new idea, whereas induction produces too simple ideas. New ideas in science are due to *abduction*, a particular kind of non-deductive[5] inference that involves the generation and evaluation of explanatory hypotheses.

Many attempts have been made to model abduction by developing some formal tools in order to illustrate its computational properties and the relationships with the different forms of deductive reasoning [14]. Some of the formal models of abductive reasoning are based on the theory of the *epistemic state* of an agent [15], where the epistemic state of an individual is modeled as a consistent set of beliefs that can change by expansion and contraction (*belief revision framework*). These kinds of logical models are called sentential [8]. Deductive models of abduction may be characterized as follows. An explanation for β relative to background theory T will be any α that, together with T, entails β (normally with the additional condition that $\alpha \cup T$ be consistent). Such theories are usually generalized in many directions: first of all by showing that explanations entail their conclusions only in a *defeasible*

[2] Magnani [8, 12] introduces the concept of theoretical abduction. He maintains that there are two kinds of theoretical abduction, "sentential", related to logic and to verbal/symbolic inferences, and "model-based", related to the exploitation of internalized models of diagrams, pictures, etc., cf. below in this paper.

[3] Manipulative abduction and epistemic mediators are introduced and illustrated in [8].

[4] Peirce clearly contrasted abduction to induction and deduction, by using the famous syllogistic model. More details on the differences between abductive and inductive/deductive inferences can be found in [8, 13].

[5] Non-deductive if we use the attribute "deductive" as designated by the classical logic.

way (there are many potential explanations), so joining the whole area of the so-called nonmonotonic logic or of the probabilistic treatments; second, trying to show how some of the explanations are relatively implausible, elaborating suitable technical tools (for example in terms of modal logic) able to capture the notion of preference among explanations.

The idea of consistency that underlies some of the more recent deductive consistency-based models of selective abduction (diagnostic reasoning) is the following: any inconsistency (anomalous observation) refers to an aberrant behavior that can usually be accounted for by finding some set of components of a system that, if behaving abnormally, will entail or justify the actual observation. The observation is anomalous because it contradicts the expectation that the system involved is working according to specification. This types of deductive models go beyond the mere treatment of selective abduction in terms of preferred explanations and include the role of those components whose abnormality makes the observation (no longer anomalous) consistent with the description of the system (see [15] and [16]).

This kind of *sentential frameworks* exclusively deal with selective abduction (diagnostic reasoning)[6] and relate to the idea of preserving *consistency*. Exclusively considering the sentential view of abduction does not enable us to say much about creative processes in science, and, therefore, about the nomological and most interesting creative aspects of abduction. It mainly refers to the *selective* (diagnostic) and merely *explanatory* aspects of reasoning and to the idea that abduction is mainly an inference *to the best explanation* [8].

The sentential view, when used to express the creativity events it is either empty or replicates the well-known *Gestalt* model of radical innovation. It is empty because the sentential view stops any attempt to analyze the creative processes: the event of creating something new is considered so radical and instantaneous that its irrationality is immediately involved.

For Peirce abduction is an *inferential process* that includes all the operations whereby hypotheses and theories are constructed. Hence abduction has to be considered as a kind of *ampliative* inference that, as already stressed, is not logical and truth preserving: indeed valid deduction does not yield any new information, for example new hypotheses previously unknown.

3 Change and Chance

Chance discovery and production is described through the cognitive analysis of some typical internal abductive processes (for example through radical innovations) that human beings exploit in science. Moreover, we will see that especially concrete manipulations of the external world constitute a fundamental passage in chance discovery: by a process of manipulative abduction

[6] As previously indicated, it is important to distinguish between *selective* (abduction that merely selects from an encyclopedia of pre-stored hypotheses), and *creative* abduction (abduction that generates new hypotheses).

it is possible to build prostheses (*epistemic mediators*) for human minds, by interacting with external objects and representations in a constructive way. Moral chance too involves mediators and manipulations of external objects and tools. My notion of chance is so related both to the cognitive aspects of conceptual change and radical innovation and to the role of extra-theoretical dimensions.

3.1 The Internal Side of Abductive Reasoning

If we want to provide a suitable framework for analyzing the most interesting cases of conceptual changes in science we do not have to limit ourselves to the *sentential* view of theoretical abduction but we have to consider a broader *inferential* one: the *model-based* sides of creative abduction (cf. below).

Usually the sentential models of theoretical abduction are limited, because they do not capture other reasoning tasks [17]:

1. the role of statistical explanations, where what is explained follows only probabilistically and not deductively from the laws and other tools that do the explaining;
2. the sufficient conditions for explanation;
3. the fact that sometimes the explanations consist of the application of schemas that fit a phenomenon into a pattern without realizing a deductive inference;
4. the idea of the existence of high-level kinds of *creative* abductions;
5. the existence of model-based abductions;
6. the fact that explanations usually are not complete but only furnish *partial* accounts of the pertinent evidence (see [18]);
7. the fact that one of the most important virtues of a new scientific hypothesis (or of a scientific theory) is its power of explaining *new*, previously *unknown* facts: "[...] these facts will be [...] unknown at the time of the abduction, and even more so must the auxiliary data which help to explain them be unknown. Hence these future, so far unknown explananda, cannot be among the premises of an abductive inference" (see [19]), observations become real and explainable only by means of new hypotheses and theories, once discovered by abduction.

From the Peirce's philosophical point of view, all thinking is in signs, and signs can be icons, indices or symbols. Moreover, all inference is a form of sign activity, where the word sign includes "feeling, image, conception, and other representation" [20, 5.283], and, in Kantian words, all synthetic forms of cognition. That is, a considerable part of the thinking activity is model-based. Of course model-based reasoning acquires its peculiar creative relevance when embedded in abductive processes, so that we can individuate a *model-based abduction*.

Hence, it is in terms of *model-based abduction* (and not in terms of sentential abduction) that we have to think to explain complex processes like scientific conceptual change. Related to the high-level types of scientific conceptual change [21] are different varieties of *model-based abductions* [17]. Following Nersessian [22], the term “model-based reasoning” is used to indicate the construction and manipulation of various kinds of representations, not mainly sentential and/or formal, but mental and/or related to external mediators. Although it is controversial as to whether there is any form of representation other than strings of symbols, it is possible, following Johnson-Laird (see [23]), to assume the existence of at least three kinds of *mental* representations:

1. *propositional representation* (strings of symbols such as “the pot is on the table”);
2. *mental models* (structural analogs of real world or imagined situations, such as a pot being on a table);
3. *images* (a mental model from a specific perspective, such as looking down on the pot on the table from above).

Mental models [23] perform a kind of internal model-based reasoning. Other examples of model-based reasoning are constructing and manipulating visual representations, thought experiment, analogical reasoning, but also the so-called “tunnel effect” [24], occurring when models are built at the intersection of some operational interpretation domain - with its interpretation capabilities - and a new ill-known domain.

3.2 Finding Inconsistencies by Radical Innovation

It is well-known that the derivation of inconsistencies contributes to the search for alternative, and possibly new, hypotheses [10, 25]. For each assumption which contributes to the derivation of a contradiction there exists at least one alternative new system obtained by abandoning or modifying the assumption. In science anomalies result not only from direct conflicts between inputs and system knowledge but also from conflicts between their ramifications. Any explanation must be suitably plausible and able to dominate the situation in terms of reasonable hypotheses. Moreover, the explanation has to be relevant to the anomaly, and resolve the underlying conflict. Finally, in some cases of everyday (and practical) anomaly-driven reasoning the explanation has to be useful, so it needs information that will point to the specific faults that need repair.

The classical example of a theoretical system that is opposed by a contradiction is the case in which the report of an empirical observation or experiment contradicts a scientific theory. Whether it is more beneficial to reject the report or the statement of the theory depends on the whole effect on the theoretical system. It is also possible that many alternatives might lead to non-comparable, equally viable, but mutually incompatible, systems. Why were the photographic plates in Rntgen laboratory continually blackened? Why does the perihelion of the Mercury planet advance? Why is the height of the barometer lower at the high altitudes than at the low ones?

Surely surprise and curiosity are related to the detection of inconsistencies [8, chapter 6]. *Internal* model-based abductive ways of generating a hypothesis that explains some phenomenon or conceptual problem that produced the question are heuristically linked to the activity itself both of *finding* that certain puzzling phenomenon or that particular conceptual problem or of *eliciting* that certain "hidden" phenomenon or conceptual problem. Hence, they are related to the activity of finding and producing chance. We will see (cf. section "Extracting ethical chance through manipulative abduction") that also from the perspective of a kind of reasoning we can call *external* (i.e. manipulative) typical templates of epistemic acting are still devoted to generate inconsistencies and curiosities as new *trends* to reach - abduce - new hypotheses.

Empirical anomalies result from data that cannot currently be fully explained by a theory. They often derive from predictions that fail, which implies some element of incorrectness in the theory. In general terms, many theoretical constituents may be involved in accounting for a given do-main item (anomaly) and hence they are potential points for modification. The detection of these points involves defining which theoretical constituents are employed in the production of the anomaly. Thus, the problem is to investigate all the relationships in the explanatory area. Epistemologists have analyzed this problem by providing a theory of anomaly resolution where abductive steps are present when we are trying to eliminate the already confirmed anomaly in a creative way [8, chapter 6] by generating a new hypothesis, as an explanation of it (cf. also [26]). Empirical anomalies are not alone in generating impasses, there are also the so-called *conceptual anomalies*.

The so-called conceptual problems represent a particular form of anomaly. In addition, resolving conceptual problems may involve satisfactorily answering questions about the nature of theoretical entities. Nevertheless such conceptual problems do not arise directly from data, but from the nature of the claims in the principles or in the hypotheses of the theory. The formal sciences are especially concerned with conceptual problems. Let's consider an example deriving from the well-known case of the non-Euclidean revolution, which plays a remarkable role in illustrating some actual transformations in rational conceptual systems. The discovery of non-Euclidean geometries involves some interesting cases of visual abductive (model-based) reasoning. It demonstrates a kind of visual abduction, as a strategy for anomaly resolution related to a form of explanatory and productive visual thinking (this example is analyzed in [12]).

In *Against Method*, Feyerabend [27] attributes a great importance to the role of contradiction. He establishes a "counterrule" which is the opposite of the neopositivistic one that it is "experience", or "experimental results" which measures the success of our theories, a rule that constitutes an important part of all theories of corroboration and confirmation. The counterrule

"[...] advises us to introduce and elaborate hypotheses which are inconsistent with well-established theories and/or well-established facts. It advises us to proceed counterinductively" (p. 20). *Counterinduction* is seen more reasonable than induction, because appropriate to the needs of creative reasoning in science. We know that counterinduction, that is the act of introducing, inventing, and generating new inconsistencies and anomalies, together with new points of view incommensurable with the old ones, is congruous with the aim of inventing "alternatives" ("proliferation of theories is beneficial for science"), is very important in all kinds of creative abductive reasoning. When a scientist introduces a new hypothesis, especially in the field of natural sciences, he is interested in the potential rejection of an old theory or of an old knowledge domain. Consistency requirements that govern hypothesis withdrawal and conceptual change in various ways, would arrest further developments of the new abduced hypothesis. In the scientist's case there is not the deletion of the old concepts, but rather the coexistence of two rival and competing views. Consequently we have to consider this competition as a form of epistemological, and non logical inconsistency. For instance two scientific theories are conflicting because they compete in explaining shared evidence. Moreover, counterinduction, as the introduction of inconsistencies and conflicts, promotes the chance discovery for further epistemic growth.

We have said above that from the Peirce's philosophical point of view, all inference is a form of sign activity, where the word sign includes "feeling, image, conception, and other representation" [20, 5.283]. That is, a considerable part of the inference activity is model-based. Hence, many model-based ways of reasoning are performed in a manipulative way by using external tools and mediators (cf. the following section). *Manipulative abduction* [8] happens when we are thinking through doing and not only, in a pragmatic sense, about doing. So the idea of manipulative abduction goes beyond the well-known role of experiments as capable of forming new scientific laws by means of the results (the nature's answers to the investigator's question) they present, or of merely playing a predictive role (in confirmation and in falsification). Manipulative abduction refers to an extra-theoretical behavior that aims at creating communicable accounts of new experiences to integrate them into previously existing systems of experimental and linguistic (theoretical) practices. The existence of this kind of extra-theoretical cognitive behavior is also testified by the many everyday situations in which humans are perfectly able to perform very efficacious (and habitual) tasks without the immediate possibility of realizing their conceptual explanation.

In the following section manipulative abduction will be considered from the perspective of the relationship between unexpressed knowledge and external representations. The power of model-based reasoning and abduction (both theoretical and manipulative) mainly depends on their ability to extract and render explicit a certain amount of important information, unexpressed at the level of available data. They have a fundamental role in the process of transformation of knowledge from its *tacit* to its *explicit* forms, and in the subsequent knowledge elicitation and use. It is in this process that chance discovery, promotion, and production is central. Let us describe how this happens in the case of "external" model-based processes.

4 Extracting Chance through Manipulative Abduction

4.1 Chance and Unexpressed Knowledge

As pointed out by Polanyi in his epistemological investigation, a large part of knowledge is not explicit, but tacit: we know more than we can tell and we can know nothing without relying upon those things which we may not be able to tell [28]. Polanyi's concept of knowledge is based on three main theses: first, discovery cannot be accounted for by a set of articulated rules or algorithms; second, knowledge is public and also to a very great extent personal (i.e. it is constructed by humans and therefore contains emotions, "passions"); third, an important part of knowledge is tacit.

Hence, two levels of knowledge, mutually exclusive but complementary, as they interact in creative tasks, underlie every activity: there is a kind of knowledge we can call *focal*, that is the knowledge about the object or phenomenon in focus; and another kind of knowledge, masked under the first one, and often used as a tool to handle or improve what is in focus, we can call *tacit*. The first one is the knowledge that is transmissible through any systematic language, since it can be relatively easily formulated by means of symbols and digitalized. Tacit knowledge, on the other hand, is characterized by the fact that it is personal, context specific, usually characterized as derived from direct experience, and therefore hard to elicit and communicate. It is "non-codified, disembodied know-how that is acquired via the informal take-up of learned behavior and procedures" (see [29, p. 92]).

Fleck [30] describes this form of knowledge as "a subtle level of understanding often difficult to put into words, a trained recognition and perception" (p. 119). Tacit knowledge is wholly embodied in the individual, rooted in practice and experience, expressed through skillful execution, and can become useful by means of watching and doing forms of learning and exploitation. As Polanyi contends, human beings acquire and use knowledge by actively creating and organizing their own experience: tacit knowledge is the practical knowledge used to perform a task. The existence of this kind of not merely theoretical knowing behavior is also testified by the many everyday situations in which humans are perfectly able to perform very efficacious (and habitual) tasks without the immediate possibility of realizing their conceptual explanation: they are not "theoretically" *aware* of their capabilities. In some cases the conceptual account for doing these things was at reproduce it, in other cases the account has to be constructed for the first time, like in creative experimental settings in science.

Hutchins [31] illustrates the case of a navigation instructor that for 3 years performed an automatized task involving a complicated set of plotting manipulations and procedures. The insight concerning the conceptual relationships between relative and geographic motion came to him suddenly "as lay in his bunk one night".

This example explains that many forms of learning can be represented as the result of the capability of giving conceptual and theoretical details to already automatized manipulative executions. The instructor does not discover anything new from the point of view of the objective knowledge about the involved skill, however, we can say that his conceptual awareness is new from the local perspective of his individuality.

We can find a similar situation also in the process of scientific creativity. Too often, in the cognitive view of science, it has been underlined that conceptual change just involves a *theoretical* and "internal" replacement of the main concepts. But usually researchers forget that a large part of this processes are instead due to *practical* and "external" *manipulations* of some kind, prerequisite to the subsequent work of theoretical arrangement and knowledge creation. When these processes are creative we can speak of manipulative abduction (cf. above).

Scientists need a first "rough" and concrete experience of the world to develop their systems, as a *cognitive-historical* analysis of scientific change [32] and [33] has carefully shown. The prevailing perspective among philosophers is that the processes of discovery and the consequent new incoming scientific representations are too mysterious to be understood. This view receives support from numerous stories of genius' discoveries, such as Archimedean eureka-experiences. Such accounts neglect periods of intense and often arduous thinking activity, often performed by means of experiments and *manipulative* activity on external objects; these are periods that prepare such "instantaneous" discoveries.

It is also important to understand that the scientific process is *complex* and *dynamic*: new representations do not emerge completely codified from the heads of scientists, but are constructed in response to specific problems by systematic use of heuristic procedures (as pointed out by Herbert Simon's view on the "problem-solving process" [34]). Traditional examinations of how problem-solving heuristics create new representations in science have analyzed the frequent use of analogical reasoning, imagistic reasoning, and thought experiment from an internal point of view.[7] However attention has not been focalized on those particular kinds of heuristics, that resort to the existence of *extra-theoretical* ways of thinking (*thinking through doing*, cf. [36]). Indeed many cognitive processes are centered on *external representations*, as a means

[7] The empirical "in vivo" recent research by Dunbar [35], in many molecular biology and immunology laboratory in US, Canada and Italy, has demonstrated the central role of the unexpected in creative abductive reasoning: "scientists expect the unexpected".

to create communicable accounts of new experiences ready to be integrated into previously existing systems of experimental and linguistic (theoretical) practices.

For example, in the simple case of the construction and examination of diagrams in elementary geometrical reasoning, specific experiments serve as states and the implied operators are the manipulations and observations that transform one state into another. The geometrical outcome is dependent upon practices and specific sensory-motor activities performed on a non-symbolic object, which acts as a dedicated external representational medium supporting the various operators at work. There is a kind of an epistemic negotiation between the sensory framework of the problem solver and the external reality of the diagram [12]. It is well-known that in the history of geometry many researchers used internal mental imagery and mental representations of diagrams, but also self-generated diagrams (external) to help their thinking.

This process involves an external representation consisting of written symbols and figures that for example are manipulated "by hand". The cognitive system is not merely the mind-brain of the person performing the geometrical task, but the system consisting of the whole body (cognition is *embodied*) of the person plus the external physical representation. In geometrical discovery the whole activity of cognition is located in the system consisting of a human together with diagrams.

An external representation can modify the kind of computation that a human agent uses to reason about a problem: the Roman numeration system eliminates, by means of the external signs, some of the hardest parts of the addition, whereas the Arabic system does the same in the case of the difficult computations in multiplication. The capacity for inner reasoning and thought results from the internalization of the originally external forms of representation [37].

In the case of the external representations we can have various objectified knowledge and structures (like physical symbols - e.g. written symbols, and objects - e.g. three-dimensional models, shapes and dimensions), but also external rules, relations, and constraints incorporated in physical situations (spatial relations of written digits, physical constraints in geometrical diagrams and abacuses) (see [37]). The external representations are contrasted to the internal representations that consist of the knowledge and the structure in memory, as propositions, productions, schemas, neural networks, models, prototypes, images.

The external representations are not merely memory aids: they can give people access to knowledge and skills that are unavailable to internal representations, help researchers to easily identify aspects and to make further inferences, they constrain the range of possible cognitive outcomes in a way that some actions are allowed and other forbidden. They increase the chance discoverability. The mind is limited because of the restricted range of information processing, the limited power of working memory and attention, the limited speed of some learning and reasoning operations; on the other hand the environment is intricate, because of the huge amount of data, real time requirement, uncertainty factors.

Consequently, we have to consider the whole system, consisting of both internal and external representations, and their role in optimizing the whole cognitive performance of the distribution of the various subtasks.

5 Templates of Moral Acting and Moral Mediators

We have illustrated in the previous sections that, even if, of course, a large portion of the complex environment of a thinking agent is internal, and consists of the proper software composed of the knowledge base and of the inferential expertise of the individual, nevertheless a "real" cognitive system is composed by a "distributed cognition" among people and some "external" objects and technical artifacts [31, 38].

We have introduced above the notion of *tacit knowledge*. Now we propose an extension of that concept. There is something more important beyond the tacit knowledge "internal" to the subject - considered by Polanyi as personal, embodied and context specific. We can also speak of a sort of tacit information "embodied" into the whole relationship between our mind-body system and suitable external representations. An information we can extract, explicitly develop, and transform in knowledge contents, to solve problems.

As we have already stressed, Peirce considers inferential any cognitive activity whatever, not only conscious abstract thought; he also includes perceptual knowledge and subconscious cognitive activity. For instance in subconscious mental activities visual representations play an immediate role.

Peirce gives an interesting example of model-based abduction related to sense activity: "A man can distinguish different textures of cloth by feeling: but not immediately, for he requires to move fingers over the cloth, which shows that he is obliged to compare sensations of one instant with those of another" [20, 5.221]. This surely suggests that abductive movements have also interesting extra-theoretical characters and that there is a role in abductive reasoning for various kinds of manipulations of external objects. *All* knowing is *inferring* and inferring is not instantaneous, it happens in a process that needs an activity of comparisons involving many kinds of models in a more or less considerable lapse of time. All these considerations suggest, then, that there exist a creative form of thinking through doing,[8] fundamental as much as the theoretical one: *manipulative abduction* (see [8] and [12]). As already said *manipulative* abduction happens when we are thinking *through* doing and not only, in a pragmatic sense, about doing.

In science various templates of manipulative behavior exhibit some regularities. The activity of manipulating external things and representations is

[8] In this way the cognitive task is achieved on *external* representations used in lieu of an internal ones. Here action performs an *epistemic* and not a merely performatory role, relevant to abductive reasoning.

highly conjectural and not immediately explanatory: these templates are hypotheses of behavior (creative or already cognitively present in the scientist's mind-body system, and sometimes already applied) that abductively enable a kind of epistemic "doing". Hence, some templates of action and manipulation can be selected in the set of the ones available and pre-stored, others have to be created for the first time to perform the most interesting creative cognitive accomplishments of manipulative abduction. The whole activity of manipulation is devoted to building - in the case of science - various external *epistemic mediators*[9] that function as an enormous new source of information and knowledge. Therefore, manipulative abduction represents a kind of redistribution of the epistemic and cognitive effort to manage objects and information that cannot be immediately represented or found internally (for example exploiting the resources of visual imagery).[10]

Magnani in [8, chapter 6] stresses the importance of the so-called preinventive forms in abductive reasoning. Intuitively an anomaly is something surprising, as Peirce already knew "The breaking of a belief can only be due to some novel experience" [20, 5.524] or "[...] until we find ourselves confronted with some experience contrary to those expectations" [20, 7.36]. Therefore it is not strange that something anomalous can be found in those kinds of structures the cognitive psychologists call preinventive. Cognitive psychologists have described many kinds of preinventive structures (typically unstable and incomplete) and their desirable properties, that constitute particularly interesting ways of "irritating" the mind and stimulating creativity [39]: they are certainly of interest for chance discovery and production.[11]

5.1 Building Ethical Chances

Let us come back to the problem of moral reasoning and moral deliberation I introduced in the first two sections above and so to the role of what I call moral mediators. Not only researchers in epistemology but also researchers in ethics stress the attention on the role of *imagination* respectively in scientific

[9] This expression is derived from the cognitive anthropologist Hutchins (see [31]), who coined the expression "mediating structure" to refer to various external tools that can be built to cognitively help the activity of navigating in modern but also in "primitive" settings. Any written procedure is a simple example of a cognitive "mediating structure" with possible cognitive aims, so mathematical symbols and diagrams : "Language, cultural knowledge, mental models, arithmetic procedures, and rules of logic are all mediating structures too. So are traffic lights, supermarkets layouts, and the contexts we arrange for one another's behavior. Mediating structures can be embodied in artifacts, in ideas, in systems of social interactions [...]" [31, pp. 290–291].

[10] It is difficult to preserve precise spatial and geometrical relationships using mental imagery, in many situations, especially when one set of them has to be moved relative to another.

[11] A complete treatment of the problem of chance extraction and production in the light of computational epistemology and dynamical systems is given in [40].

reasoning and in ethical thinking and deliberations. If we interpret "imagination" just as a process of knowledge gathering and shaping, it can be seen as a process which promotes new cognitive chances leading to see things as we would not otherwise have seen them. To see a "moral world" means to see the world in an original way: ethical understanding involves coming to see some aspects of reality in a particular way that influences human acting in shaping and surviving the future.

Suggestions in describing this dynamical process also come from a theory developed in the area of computer vision: the *active perception* approach [41]. This approach aims at understanding cognitive systems in terms of their environmental *situatedness*: instead of being used to build a comprehensive inner model of its surroundings, the agent's perceptual capacities are simply used to obtain whatever specific pieces of information are necessary for its behavior in the world. The agent "constantly adjusts its vantage point", updating and refining its procedures, in order to uncover a piece of information. This means specifying how to efficiently examine and explore, and thus interpret, an object of a certain type. It is a process of attentive and controlled perceptual exploration by which the agent is able to collect the necessary information: a purpose-fully moving through what is being examined, actively picking up information rather than passively transducing [42]. The world is actively explored rather than passively registered.

This description, used in analyzing both perceptual and imaginative activity can be useful in eliciting the cognitive processes underlying "moral imagination". "Moral principles without moral imagination become trivial, impossible to apply, and even a hindrance to morally constructive action" [43]. This means that in ethics analogical and metaphorical reasoning is very important, because of its capacity to "re-conceptualize" the particular situation at hand. Consequently, model-based tools for ethical deliberations should not be considered negative, as subjective, free flowing, creative processes not governed by any rule or constrained by any rationally defined concepts so that we are led to see imagination as an enemy of morality. The role of a sort of a model-based imaginative activity is clear, for instance, in the *Critique of Pure Reason*, where Kant clarifies the importance of *intermediate* thinking devices able to make human beings capable of linking abstract principles to the real world of experience (cf. the case of the role of imagination in geometrical construction). Relating the discourse to moral rules, Kant develops the idea that a pure moral rule (as a maxim of action) is applied to the concrete experience as a kind of "typification" - a sort of figurative substitute [44]. This typification could be interpreted as a kind of *figurative envisioning* of a non existing world as a means for judging a given moral situation. Kant denies that this typification involves imagination, for he maintains moral judgment a matter of pure practical reason, but, as Johnson concludes, "what could be more thoroughly imaginative than this form of figurative envisioning that is based on a metaphoric mapping?" [43]. It is through this kind of typification that chance production and promotion is enhanced in ethics. How does this occur?

Beyond rules and principles, hence, also prototypes, schemas, frames, and metaphors are vehicles of model-based moral knowledge, sometimes very efficient when facing moral problems. For example, morality as a grammar represents a typical metaphorical "prototype" exploited in ethics: grammatical principles are in analogy to moral principles like in the simple case of "speaking well" and "acting well"; action as a metaphorical "motion" leads to the idea that moral principles would be rules telling us which "action-paths" we may take, which ones we must take, and which we must never take (cit., p. 43). When looking for consequences of our moral actions and deliberations, this envisioning of a non existing world as a means for judging a proposed action can be performed in a model-based way.

As already described in the previous section, a particular kind of model-based reasoning, I have called "manipulative", occurs when we are thinking "through" doing and not only, in a pragmatic sense, about doing. We have seen it resorts to a kind of exploitation of external objects and representations, and refers to an extra-theoretical (distributed) behavior that aims at creating communicable accounts of new experiences to integrate them into previously existing systems of experimental and linguistic (theoretical) practices. It is difficult to establish a list of invariant behaviors that are able to illustrate manipulative reasoning in ethics. Certainly the expert manipulation of non-human objects in real or artificial environments implies the application of old and new *templates* of behavior that exhibit some regularities. In is important to note these templates are embodied and implicit, as tacit forms of acting: we are not referring here to the moral actions and manipulations that simply follow previous explicit and devised plans. Anyway, this moral activity is still conjectural: these templates are embedded hypotheses of moral behavior (creative or already cognitively present in the people's mind-body system, and ordinarily applied) that enable a kind of moral "doing" to extract new ethical chances. Hence, some templates of action and manipulation can be *selected* in the set of those available and pre-stored, others have to be *created* for the first time to perform the most interesting accomplishments of manipulative moral inference.

5.2 Templates of Moral Doing

Some common features of these "tacit" templates that enable us to manipulate external human and non-human things and structures to achieve new moral effects and new ethical chances are related to (cf. Figure 1):

1. sensitivity to *curious or anomalous aspects* of the moral situation. In this case manipulations are performed to reveal potential inconsistencies in received knowledge, as when we suddenly adopt a different embodied attitude toward our spouses to elicit a reaction that confirms or discounts hypotheses about their feelings or to develop new hypotheses about the relationship (cf. below). This might be the case when a man becomes more aggressive to check

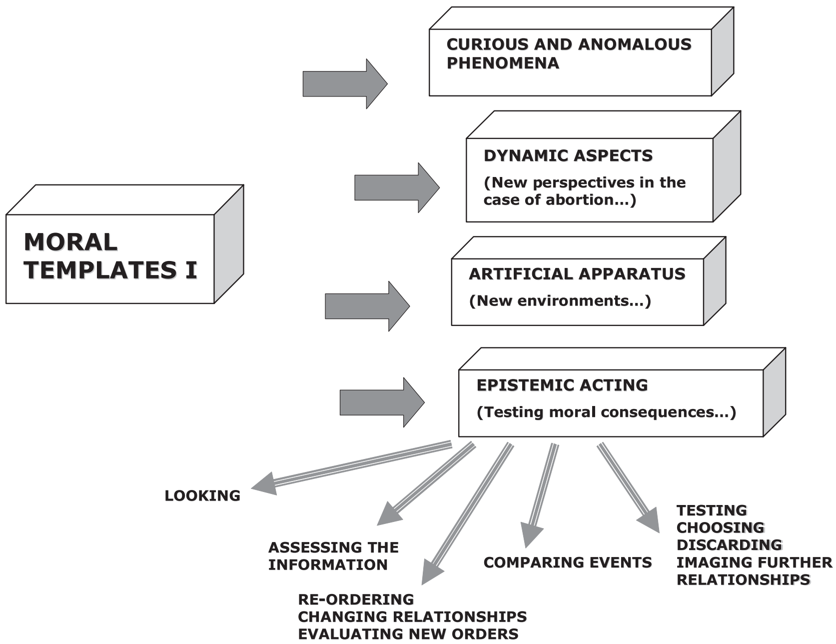

Fig. 1. Conjectural templates I.

his wife's tolerance and caring for him. Or when investigating a crime, detectives spontaneously further investigate the evidence to get more interesting data to build a moral data shape of the suspect;

2. preliminary sensitivity to *dynamical character* of the moral situation, and not only to entities and their properties. A common aim of manipulations is to practically reorder the dynamic sequence of the events and of the human relationships associated with the moral problem in order to find new options for action. An example might be a woman who, having decided to have an abortion, then spontaneously tries to modify the dynamical aspects of both her behavior and her relationships in hopes of to try to establish new perspectives helping her to envisage a possible decision different from the first one first envisaged. She is un-consciously changing her behavior in hopes of making herself decide against the abortion;

3. referral to manipulations that exploit *artificial created environments* and *externally induced feelings* to free new possibly stable and repeatable sources of information about hidden moral knowledge and constraints. This template feature is apparent, say, in a discussion of the moral problem of capital punishment when we exploit resources like statistics, scientific research, or information from interviews to gather real rather than faulty information, like the one about the genuine relief the murder victim's relatives feel when

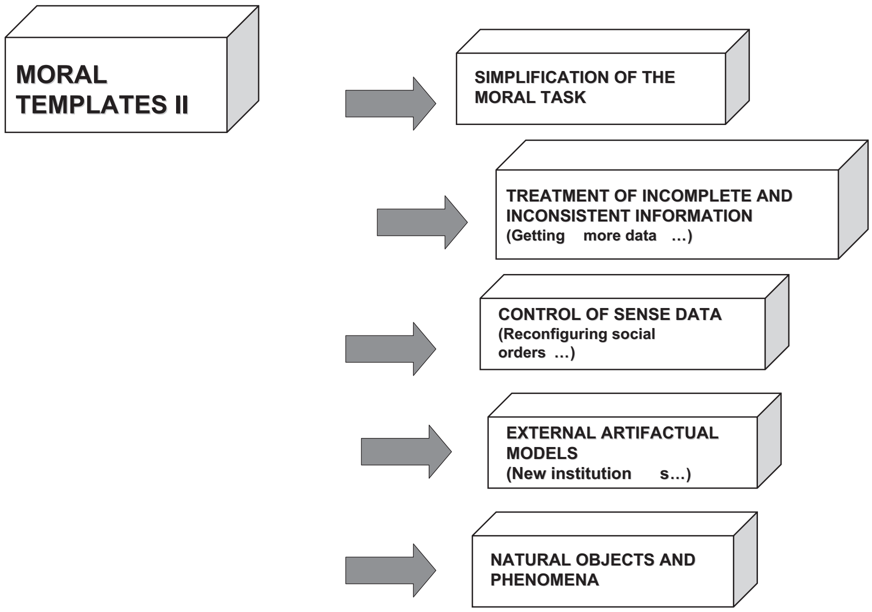

Fig. 2. Conjectural templates II.

the criminal is killed. In this way a new configuration of the social orders of the affected groups of people is achieved;[12]

4. various contingent ways of spontaneous moral acting. This case contemplates a cluster of very common moral templates. A person will automatically look at issues from different perspectives; *assess* available information; *compare* events; *test*, *choose*, *discard* and *imaging* additional manipulations; and implicitly *evaluate* possible *new orders* and *relationships* (for instance simpler orders, to facilitate analogies or comparisons).These strategies are all useful ways to get suitable evidence to test previously es-t moral judgments also through stimulating the derivation of significant consequences of those judgments[13] (cf. Figure 1);

More features of our tacit templates and ethical mediators are related to the following additional issues (cf. Figure 2) :

5) spontaneous moral action that can be useful in presence of *incomplete* or *inconsistent information* or a *diminished capacity to act morally* upon the world. Such action works on more than just a "perceptual" level - it is also used to get additional data that restores coherence and/or improves deficient knowledge;

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[12] On the reconfiguration of social orders that is realized in science (laboratories), cf. [45].

[13] Analogues of all these manipulative templates are active in epistemic settings: cf. [8, 12, 46].

6) *Action as a control of sense data* illustrates how we can change the position of our bodies (and/or of the external objects) to reconfigure social orders and collective relationships; it also shows how to exploit artificially created events to get various new kinds of stimulation. Action of this kind provides otherwise unavailable tactile, visual, kinesthetic, sentimental, emotional, and bodily information that, for example, helps us take care of other people (cf. below in the following subsection);

7) action enables us to build new *external artifactual models* of ethical mechanisms and structures (through "institutions", for example) to substitute for the corresponding "real" and "natural" ones. (Keep in mind, of course, that these "real" and "natural" structures are also artificial - our cultural concept of "family" is not a natural institution). For instance, we can replace the "natural" structure "family" with an environment better suited for an agent's moral needs, which occurs when, say, we remove a child from the care of abusive family members. In such a case we are exploiting the power of a artificial "house" to reconfigure relationships. A different setting - a new but still artificial framework - facilitates the child's recovery and allows him or her to rebuild moral perceptions damaged by the abuse. A similar effect occurs when people with addiction problems move into group homes where they receive treatment and support. An even simpler example might be the external structures we commonly use to facilitate good manners and behavior: fences, the numbers we take while waiting at a bakery, rope-and-stanchion barriers that keep lines of people in order, etc.

Of course many of the actions that are entertained to build the artifactual models above are not tacit, but explicitly projected and planned. However, imagine the people that first created these artifacts (for instance the founders of the group houses for addicted people), it is not unlikely that they created them simply and mainly "through doing" (creation of new tacit templates of moral actions) and not by following already well-established projects.

5.3 Moral Mediators

We have seen that the whole activity of manipulation is also devoted to building various external *moral mediators*[14] that function as an enormous new source of information and knowledge. We have just observed that these mediators represent a kind of redistribution of the moral effort through managing objects and information in such a way that we can overcome the poverty and the unsatisfactory character of the moral options immediately represented or found internally (for example exploiting the resources in terms of merely internal/mental moral principles, utilitarian envisaging, and model-based moral reasoning). It is clear by this description how this kind of *manipulation* helps

[14] I derive this expression from the epistemic mediators I introduced in [8, chapter 3] and described in the previous sections: these consist of external representations, objects, and artifacts that are relevant in scientific discovery and reasoning processes.

human beings in imaging their world. Moral mediators play an important role in reshaping the ethical worth of human beings and collectives. For example they especially involve a continuous reconfiguration of social orders aiming at discovering and rebuilding new possible *moral chances* and world views.

Not only a way for moving the world to desirable states, action performs a moral and not just merely performatory role: people structure their worlds to simplify and solve moral tasks when they are in presence of incomplete information or possess a diminished capacity to morally act upon the world when they have insufficient opportunities to know. *Moral mediators* are also used to exploit latent constraints in the human-environment system. These elicited new constraints grant us additional and precious ethical information and promote chance production and discovery: when we spontaneously act in a way in which we spend more quality time with our partner to save our marriage, then our actions automatically cause variables relating to "unexpected" and "positive" contents of the relationship to covary with perceptible new released informative, sentimental, sexual, and, in general, bodily variables (cf. Figure 3). Prior to the adoption of the new reconfigured "social" order of the couple, there is no active constraint between these hidden and overt variables causing them to carry information about each other.

Also natural phenomena can play the role of external artifactual moral mediators. Many external things that usually are (or in the past were) inert

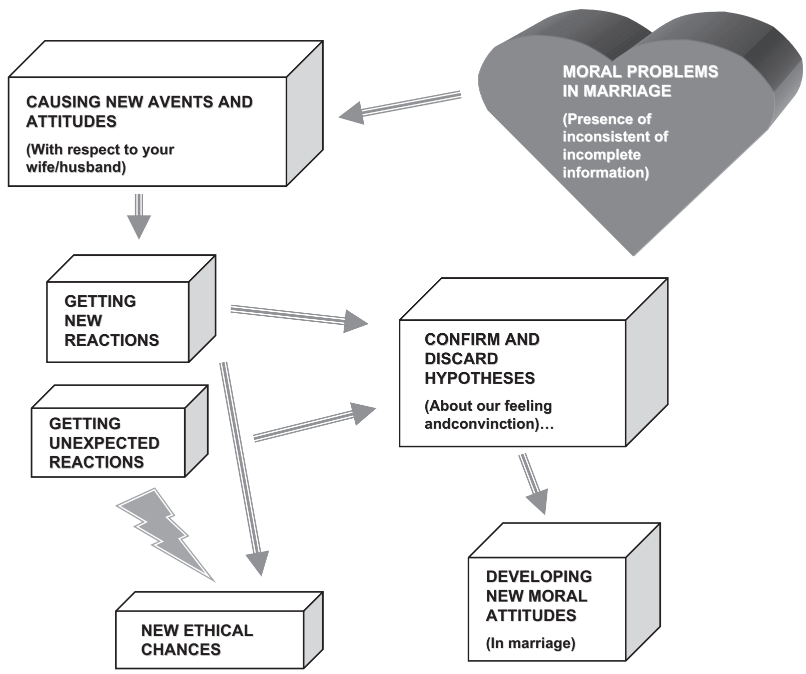

Fig. 3. The extra-theoretical dimension of ethical chance in marriage.

from the moral point of view can be transformed into moral mediators. For example we can use animals to depict new moral features of living objects previously unseen, as we can do with earth or (non natural) cultural objects; we can also use external "tools" like writing, narratives, others persons' information, rituals, various kinds of pertinent institutions to reconfigure previously given social orders morally unsatisfactory. Hence, not all of the moral tools are inside the head, many of them are shared and distributed in external objects and structures which function as ethical devices.

The external moral mediators are endowed with functional properties as components of a memory system crossing the boundary between person and environment (for example they are able to transform the tasks involved in allowing simple manipulations that promote further moral inferences at the level of model-based abduction): I can only enhance my bodily chances to experience pain through action by following the template *control of sense data*, we previously outlined, that is through changing - unconsciously - the position of my body and its relationships with other humans and non-humans embedded in distressing experiences. In many people moral training is often related to these kinds of spontaneous (and "lucky") manipulations of the control of their own body and sense data so that they build their morality immediately and non reflectively "through doing".[15]

Women taught all human beings the importance of attitudes that emphasize intimacy, caring and personal relationships.[16] It would seem that women's basic moral orientation is "taking care" of others and of external things in a personal way, not just being concerned by humanity or by the world in general. The ethics of care does not consider "obligation" as essential; moreover, it does not require that we impartially promote the interests of everyone alike. It looks on small-scale relationships with people and objects, so that it is not important to "think" to help disadvantaged children in all the world (like men aim at doing) but to "do" that when needed, just "over there". In light of my philosophical and cognitive treatment of the problem of moral model-based thinking and of morality "through doing", this female attitude does not have to be considered as less rational and deontological because more related to emotions and passions, in turn intended as forms of lower level of thinking. I contend that we can become "more loving parents" in a more intuition and feeling oriented way because of the reasons - and may be because of "Kantian" rules - that compel us to educate our feelings in that way, and so to privilege the "taking care" of our children in certain situations. The route from reason to feeling (and of course also from feeling to reason) is continuous in ethics.

[15] I have treated in detail the problem of moral mediators in the light human dignity in our technological era in [2].

[16] On the role of feminist skepticism in ethics, and the so-called "expressive-collaborative model" of morality cf. [47]. This model looks at moral life as "a continuing negotiation among people, a socially situated practice of mutually allotting, assuming, or deflecting responsibilities of important kinds, and understanding the implications of doing so" (p. 276). Or course this is contrasted to the so-called "theoretical-juridical conception of morality".

Consequently, “taking care” is a “different” chance for looking at people and objects, and, as a form of morality immediately given “through doing”, is clearly integrated and explained as a fundamental kind of moral inference and knowledge. Ethics of care, indeed, relates to the habit of terminating some people’s urgencies by performing a “caring perception” of non-humans (objects inside the house, for example). Consequently, these non-humans can easily be seen as “moral mediators” in the sense that I give to this cognitive concept.

When I clean my computer I take “care” of it by contemplating its economical and instrumental worth and its worth as a tool for other humans. When I use my computer as an epistemic or cognitive mediator for my research or didactic activities I am considering its intellectual prosthestic worth. If we want to respect people as we respect computers, in these two cases we can learn and stress different moral features about humans: 1) humans are biological “tools” who embed economical and instrumental values, I can “use” a human to learn things, and its know how (like in the case of the hard disk with its software) - so humans are instrumentally precious for other humans in sharing skills of various kinds; 2) humans are skillful cognitive problem solvers who em-bed the moral and intrinsic worth of cognition.

6 Conclusion

It is clear that the manipulation of external objects helps human beings in chance discovery and production and thus in their creative tasks. I have illustrated the strategic role played by the so-called traditional concept of “implicit knowledge” in terms of the recent cognitive and epistemological concept of manipulative abduction, considered as a particular kind of abduction that exploits external models endowed with delegated cognitive roles and attributes.

By exploiting the concept of “thinking through doing” and of manipulative abduction I have tried to shed new light on some of the most interesting cognitive aspects of creative ethical reasoning of what I call “moral mediators”. Indeed, I contend that the whole activity of manipulation can be seen as an activity for building various external “moral mediators” that function as an enormous new source of information and knowledge and of chance extraction and production. Furthermore, while describing morality “through doing” a list of “moral templates” as forms of invariant behaviors that are able to illustrate manipulative ethical reasoning is furnished. These templates are forms of behavior which are inclined towards providing ethical outcomes.

The application of old and new (creative) moral templates of behavior exhibits some regularities and expresses expert manipulation of human and non-human objects in real or artificial environments. These templates are embodied and implicit as tacit forms of acting which prefigure new ethical chances. They are embedded hypotheses of moral behavior (creative or already cognitively present in the people’s mind-body system, and ordinarily applied) that enable a kind of moral "doing". Hence, some templates of action and manipulation can be selected in the set of those available and pre-stored, while others have to be created for the first time in order to perform the most interesting accomplishments of manipulative moral inferences. These "tacit" templates enable us to manipulate external human and non-human things and structures to achieve new moral effects and new ethical chances.

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A NeuroCognitive Approach to Decision-Making in Chance Discovery

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Summary. Chance discovery is the identification of, and to become conscious to, an event or situation (referred to as a 'chance') that is significant to human decision-making. A 'chance' may be perceived as an opportunity or a risk; and knowledge is the basis to developing awareness/recognition to such an event. Responding to and acting on such phenomena requires conscious decision-making, which is generally guided by rational reasoning with existing knowledge. Hence, there are two important facets to chance discovery: developing the cognitive awareness to a 'chance' and responding to it in a rational way. This chapter proposes the use of a brain-inspired hippocampal-like learning memory model named GenSoFNN embedded with an approximate analogical reasoning schema to functionally model the knowledge construction process of the real world relationships by the human brain. The acquired knowledge base of the GenSoFNN memory system forms a basis to develop cognitive awareness to a 'chance' event and facilitates the subsequent rational response to such a phenomenon through decision-making supported by formalized reasoning. The validity of this neurocognitive approach to decision-making in chance discovery is subsequently evaluated by employing the hippocampal-inspired GenSoFNN memory model to dynamically model the insulin profile of the human glucose metabolic process. The objective is to approximate the insulin dynamics required to achieve normoglycemia in the presence of exogenous disturbances due to food ingestions, which are perceived as risks leading to prolonged periods of elevated blood glucose levels if left untreated in diabetics. The primary results are encouraging and a Pearson correlation of over 90% is achieved.

1 Introduction

Chance discovery is to become aware of and to develop consciousness to an event or a situation, which is referred to as a 'chance' that has significant impact on human decision-making [1]. Such an event can be conceived either as an *opportunity* or a *risk*: it is an opportunity if it leads to possible gains when exploited or a risk when losses are expected and evasive or risk aversion actions are required. The significance of a 'chance' depends on the outcome of the

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evaluation of its impacts on the possible consequences and how it affects future decisions. These considerations define the appropriate subsequent actions or responses to be accorded to such phenomena. Chance discovery consists of two important facets: that is, developing awareness to and the initial identification of a 'chance' event, followed by an evaluation of the designated phenomenon in order to determine the subsequent response(s). Responding to and acting on a 'chance' event requires conscious decision-making, which is generally guided by rational reasoning with an existing body of knowledge. This second aspect of chance discovery has been referred to as *chance management* [2] in the literature.

Chance discovery requires awareness of a chance [1]. Without the relevant fundamental knowledge, chance discovery is *not* possible as one would not be able to recognize a phenomenon as a chance when it occurs, and to become aware of it. In [3], the authors argued for some kind of discontinuity of thinking, where counterexamples are generated to cause *cognitive dissonance* [4] to the learner, to facilitate a chance for the acquisition of new knowledge. Hence, the human subject requires an existing set of knowledge that contributes to the formulation of self-cognition, beliefs and perceived hypotheses before counterexamples can be employed to stimulate learning. Such a discontinuity in thinking can also be achieved through a *change* in conceptualization [5] by generalizing and applying existing knowledge across different domains and employing the reasoning strategy of perspective taking, giving rise to the opportunity for improved solutions [6]. The importance of acquired knowledge to chance discovery is further addressed in [7], where the role of *implicit memory* [8, 9] to facilitate a reduced degree of awareness to the occurrence of a 'chance' event is investigated; and the numerous publications in the literature on applying knowledge engineering systems to the task of chance discovery [10, 11, 12] reinforces the notion of knowledge expedited discovery of chances. Furthermore, John Holland [13] asserted that humans are very efficient at forming internal or mental models of the situations they are dealing with, and rerunning these scenarios in their minds (as memories) to look ahead, anticipate consequences, and seeing, recognizing and matching patterns. The underlying basis of these cognitive faculties is the ability to acquire knowledge and store them for future use, that is, *learning* and *memory*. Neuropsychological studies on human and animal memory have established the existence of multiple brain systems for memory, namely *declarative* (explicit), *procedural* (implicit) and *emotional* memories [9]. In this chapter, the importance of the human declarative memory system to chance discovery is assumed from the discussions of [2] and [3].

Rational reasoning, on the other hand, is the capacity to use the faculty of reason to facilitate logical thinking. When used in scientific and mathematical terminology, the word *reason* serves either as an explanation given to justify a motivation for performing an action or as a description of the relationships between entities, whether physical, logical, or mathematical. Reason is a derivative of knowledge; and rationality is a central principle in artificial intelligence where a rational computing system always selects the action that maximises its expected performance, given all of the knowledge it currently possesses. Rationality is a much broader term than logic, as it includes "uncertain but sensible" arguments based on probability, expectation, personal experience and the like, whereas logic deals principally with provable facts and demonstrably valid relations between them. However, this broad definition of rational reasoning is beyond the scope of the chapter. In this work, rationality is defined as a product of logical reasoning.

Hence, chance discovery requires the acquisition of novel information, the transformation of such information into a knowledge base to facilitate the identification of a chance phenomenon, and the subsequent definition of a rational response through decision-making by logical reasoning. Developing intelligent systems and computing techniques to meet such complex demands can draw inspiration from the human way of learning and reasoning with information. The brain is the biological mechanism responsible for the human intelligence, where complex networks of neurons collaborated to create a massive information computing structure. The most profound and fascinating aspects of the human intelligence are arguably the capability for learning and memory. *Learning* is defined as a process that results in a consistent change in behavioral responses through repeated exposure to the environmental stimuli or exemplar [14] and *memory* is the storage of this learned knowledge [15] for future use. Currently, the focus of neurocognitive science research is to acquire a deep understanding of how information is represented, organized, manipulated and used within the structures of the nervous system; and how such brain processes create the high-level cognitive capabilities that are manifested in the human mind. One of the main research interests in this field is centered on the study and development of functional models of brain systems that exhibit the ability to learn (i.e. they readily acquire knowledge from the exogenous inputs) and to store the acquired knowledge for later use. This subsequently leads to the construction of computational models of learning memory systems. However, such models do not attempt to depict every physiological detail of the corresponding memory systems in the brain. The aim is instead for a functional description of the high-level faculties, mechanisms and processes involved in learning and memory formation. Admittedly, although it would be interesting to develop more physiologically realistic models, this is clearly not possible with the limited knowledge of the human brain.

This chapter proposes the use of a brain-inspired hippocampal-like evolving semantic memory model named *generic self-organising fuzzy neural network* (GenSoFNN) [16] embedded with an *approximate analogical reasoning schema* (AARS) [17] to functionally model the knowledge construction process of the real world relationships by the human brain. The network is henceforth referred to as GenSoFNN-AARS and constitutes a brain-inspired engineering approach to the science of decision-making in chance discovery. In particular, the GenSoFNN-AARS system is employed to model the insulin profile of the human glucose metabolic process in order to determine the insulin dynamics required to achieve homeostasis of the metabolic process when perturbed by food intakes. This constitutes a key component to the successful management of Type-1 diabetes, which essentially requires the capability to maintain long-term near-normoglycemia state of the diabetic patient. The structure of the GenSoFNN-AARS network is inspired by a subcortical brain region known as the *hippocampus* [18] and emulates the information handling and knowledge acquisition of the hippocampal memory [19]. The key strengths of the proposed GenSoFNN-AARS learning memory model are a logically formalized reasoning process and the auto-generation of intuitive and highly comprehensible IF-THEN fuzzy rules to explain the organization, patterns and data structure uncovered or induced from the numeric training data. This forms a basis to developing awareness to the occurrence of a 'chance' event and facilitates a rational response to such a phenomenon through decision-making by the embedded AARS fuzzy inference scheme.

This chapter is organized as follows. Section 2 briefly describes the neurophysiological findings and functional memory faculties of the subcortical hippocampal region that has inspired the development of the GenSoFNN semantic memory model. Section 3 outlines the hippocampus-like structure of the GenSoFNN architecture from which the GenSoFNN-AARS network is derived and highlights the dynamically evolving nature of the GenSoFNN network that is inspired by the primary learning mechanism of the hippocampal region. Section 4 presents an overview of the GenSoFNN-AARS memory model, and briefly discusses its formalized computation process based on analogical reasoning. Section 5 highlights the task of modeling the insulin profile of the human glucose metabolic process using the GenSoFNN-AARS learning memory system to determine the insulin dynamics required to achieve normoglycemia of the metabolic process when perturbed by food intakes. Section 6 concludes this chapter.

2 Hippocampus and the Human Declarative Memory System

Neuroscience and cognitive psychological studies have revealed that a subcortical brain structure known as the *hippocampus* is involved in cognitive information processing as well as critical for the formation of long-term *declarative memory* [9]. The evidences from both studies on human and animal amnesia [8] and from brain imaging studies on humans [20] pointed to an important role for the hippocampus in encoding complex information that contributes to memories for personal experiences, that is, episodic memories, and for the ability to synthesize this episodic information into one's body of world knowledge, fact or semantic memory [21]. This constitutes the human declarative memory system. The hippocampus is essential for the perceptual processing of information regarding space, time and relationships among entities and hence functioned as a multimodal information integrator and processing center [15].

There is a commonality underlying these functions of the hippocampus; that is its ability to learn or acquire association between the various sensory inputs and to transform these excitatory signals into semantic (meaningful) knowledge [22]. In addition, the hippocampus does not store information for extended periods of time but rather serves as an intermediate-duration memory buffer that is involved in maintaining stored knowledge or memories until they are transferred for more permanent storage in various regions of the cerebral cortex (cerebrum) [15]. Thus, the hippocampus is essential for *memory consolidation* [23] by playing a role in converting short-term sensory signals to long-term or permanently encoded memories at the neocortex. Neurobiology has also established that the role of the hippocampus in memory formation and its associated function as an intermediate-term memory buffer before the memories are transferred to long-term storage sites at the associative regions of the neocortex is modulated by a cellular mechanism known as *Long-Term Potentiation* (LTP) [9, 18]. Currently, proposed computational models of the hippocampal region generally fall into two main categories: (1) models of the role of the hippocampal region in incremental learning (formation of new memories where novel knowledge is readily acquired and manipulated) [19, 24, 25] and (2) models that focus on the role of the hippocampal region in the storage and retrieval of memories. That is, the consolidation of knowledge in the short-term memory which is in a labile state to stable, more permanent storage in the long-term memory sites located in the associative areas of the neocortex [26, 27].

3 GenSoFNN: A Brain-inspired Hippocampal-like Learning Memory System

The *generic self-organising fuzzy neural network* (GenSoFNN) [16] is a brain-inspired computational model that was developed to function as a hippocampus-like learning memory structure. Its primary role is to model the incremental learning capability of the hippocampus by adopting a dynamically evolving structural learning strategy. The connectionist structure of the GenSoFNN network is depicted as Fig. 1. The GenSoFNN model epitomizes the information handling and knowledge acquisition capabilities of the hippocampal region located in the medial temporal lobe of the human brain.

As mentioned earlier, the hippocampus played a significant role in the formulation of *explicit declarative memory* and the consolidation of such newly formed memories into long-term memories [9, 23]. Hence, the hippocampus possesses attractive cognitive capabilities to incrementally conceive high-level semantic knowledge from low-level excitatory information. The GenSoFNN network is thus developed to emulate such characteristics for the extraction of high-level semantic IF-THEN fuzzy rules to explain the inherent data structures and relationships from the low-level numeric training data that is presented to it.

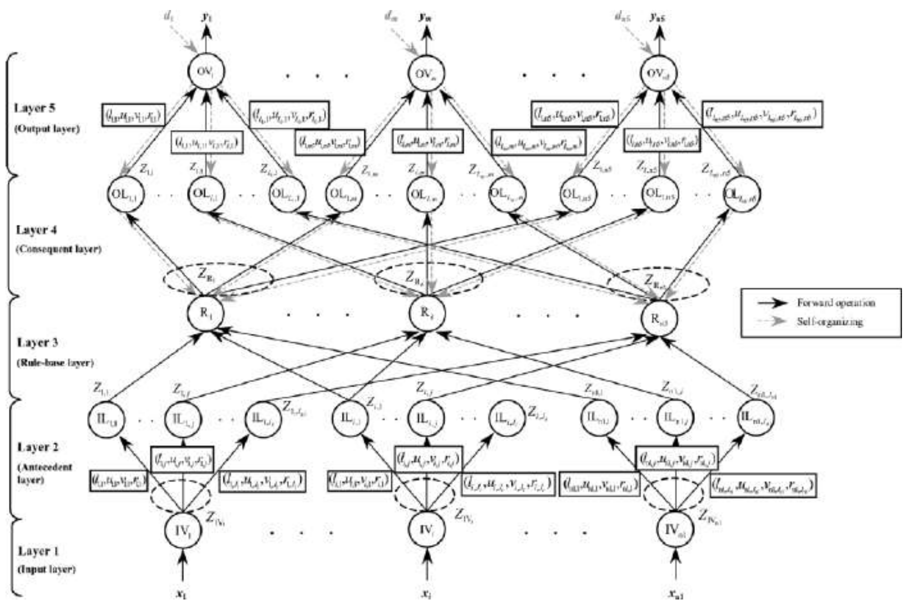

Fig. 1. Structure of the GenSoFNN network.

The GenSoFNN network consists of five layers of neurons or computing nodes. The vector $X = [x_1, \ldots, x_i, \ldots, x_{n1}]^T$ represents the inputs to the network while the vector $Y = [y_1, \ldots y_m, \ldots, y_{n5}]^T$ denotes the outputs of the GenSoFNN network with respect to the input X. In addition, the vector $D = [d_1, \ldots, d_m, \ldots, d_{n5}]^T$ represents the desired network outputs required during the *parameter-learning* phase of the training cycle. The training cycle of the GenSoFNN network consists of three phases: *Self-organizing*, *Rule formulation* and *Parameter learning*. Details of the training cycle are reported in [28, 29]. The trainable weights of the GenSoFNN network are embedded in layers 2 and 5 (enclosed in rectangular boxes in Fig. 1). Layer 2 (5) links contain the parameters of the input (output) fuzzy sets. These trainable weights (parameters) are interpreted as the corners of the trapezoidal-shaped fuzzy sets computed by the integrated *discrete incremental clustering* (DIC) technique [30]. They are denoted as l and r (left and right support points), and u and v (left and right kernel points). The subscripts denote the pre and post-synaptic nodes respectively. The weights of the remaining connections are unity.

The GenSoFNN network employs an incremental and dynamic approach to the identification of the knowledge (fuzzy rules) that defines its connectionist structure. That is, linkages and nodes defining the fuzzy rules (and hence the network structure) are added or pruned when necessary to efficiently capture the inherent knowledge induced from the training data. It is this evolving nature that ensures the GenSoFNN network auto-generates a concise fuzzy rule-base to encapsulate the formulated high-level semantic knowledge and to consistently adapt to continuing changes. This is analogous to the incremental learning function of the hippocampus, where excitatory signals from the motor cortex, visual cortex (occipital lobe) and auditory cortex (temporal lobe) etc projecting into the hippocampus through the parahippocampal region (the perirhinal, parahippocampal and entorhinal cortices) are aggregated into temporary memory traces. In addition, the rule (network structure) generation and learning algorithm of the GenSoFNN network is designed based on the notion of LTP, the primary mechanism of learning in the human hippocampus structure [9].

From a computational point of view, the GenSoFNN network is developed as one generic learning memory architecture such that well-established fuzzy logical inference schemes can be used to define the computational functions of its respective layers of computing nodes. This sought to introduce meaning to the computational steps of the GenSoFNN network, transforming it into a 'white-box' computing structure and introduce semantic interpretation to its overall architecture since the human brain store knowledge in terms of meanings. In this work, the *approximate analogical reasoning schema* (AARS) [17] fuzzy reasoning scheme is mapped to the GenSoFNN network to create GenSoFNN-AARS.

4 GenSoFNN-AARS

The GenSoFNN-AARS network is developed by mapping the operations of the AARS inference scheme onto the generic structure of the GenSoFNN semantic memory model. This section briefly describes the theoretical considerations behind analogical reasoning and demonstrates how the AARS inference process can be intuitively partitioned into five steps, which are then logically mapped to each of the five layers of the GenSoFNN-AARS network to define its computation process.

4.1 Analogical Reasoning for Problem Solving

Analogical reasoning [31] has been extensively studied in the field of philosophy [32], psychology [33], and artificial intelligence (AI) [34, 35]. It is an important source of practical reasoning and analogical reasoning is a powerful tool for *problem solving* [36]. It is particularly useful in *ill-defined*, *complex* and *novel* situations where the search space for a solution may be extremely large or there is no known solution. Hence, analogical reasoning can be employed to guide the search for a solution to such a *target* problem by modifying or drawing inference from the solution to a similar (and often well-studied) *source* problem. Analogical reasoning employs *knowledge exploitation*. In analogical reasoning, one needs to have knowledge of both the target problem and the source problem and its solution. Subsequently, the solution to the target problem is deduced by forming an analogy between the characteristics of the source and target problems.

Philosophy has provided the conceptual frameworks, definitions and justification for analogical reasoning [37] while psychology has contributed through the cognitive research on the use of analogy in reasoning and problem solving, culminating with the formalization of the various models of knowledge representation [38, 39] and the identification of the cognitive sub-processes performed during analogical reasoning [40, 41]. In AI, the research in analogical reasoning is greatly motivated by the desire to emulate human-like "intelligent" behaviors, where the ultimate goal is to develop *flexible* and *powerful* computational systems [42, 43, 44]. For the interested reader, please refer to [45] for a more detailed treatment on the subject of analogical reasoning and the various computational problem-solving approaches based on analogical reasoning.

4.2 AARS: The Approximate Analogical Reasoning Schema

Turksen and Zhong [17] have proposed an *approximate analogical reasoning schema* (denoted as AARS) which synergies the strengths of fuzzy sets theory [46] and analogical reasoning. AARS functions as a fuzzy inference scheme and harnesses the powerful mechanisms of analogical reasoning that are aptly demonstrated in human reasoning to perform *approximate reasoning* [47, 48] in fuzzy rule-based systems. AARS avoids going through the conceptually complicated mathematical computations of other well-established fuzzy inference schemes such as the *compositional rule of inference* (CRI) [49] and the *truth-value restriction* (TVR) [50] reasoning processes. It uses a *similarity measure* of the presented inputs to the rule antecedents in the knowledge base and a threshold τ to determine whether a fuzzy rule should be fired or inhibited. Subsequently, a *modification function* is employed to deduce the appropriate consequents. Hence, AARS simplifies the inference process in fuzzy rule-based systems and elevates it to a level more intuitive to the human cognitive process by associating the fuzzy inference process with analogical reasoning. The AARS inference process can be intuitively partitioned into five steps as shown by Fig. 2.

If the input is crisp, as in most control and pattern classification applications, the input has to be *fuzzified*. This is performed in Step 1 of Fig. 2. If the input is already a fuzzy set (hence "x is $\widetilde{A}$" is a fuzzy proposition), then Step 1 is unnecessary. Subsequently, Step 2 is responsible for the computation of the similarity measure S_{AARS} between the input proposition and the antecedent of a fuzzy rule in the knowledge base of the rule-based system. Step 3 evaluates the condition "$S_{AARS} \geq \tau$" to determine whether a fuzzy rule is to be fired or inhibited. If the condition is $TRUE$, then the fuzzy rule is

Fig. 2. The AARS inference process. The knowledge base of the rule-based system consists of fuzzy rules of the form "IF x is A THEN y is B".

activated. Step 4 follows only when the condition "$S_{AARS} \geq \tau$" is satisfied. The desired conclusion "y is $\widetilde{B}$" is derived from the consequent "y is B" of the fired fuzzy rule using a predetermined modification function. At Step 5, the fuzzified conclusion "y is $\widetilde{B}$" is *defuzzified* to produce a crisp output that may represent a control action or a classification decision.

Each of the five steps of the AARS reasoning process highlighted above is subsequently mapped to the corresponding layer in the generic structure of the brain-inspired hippocampal-like GenSoFNN semantic memory model. However, there are several significant shortcomings in the computations of the AARS inference process, and modifications to the original AARS are performed prior to the mapping. This eventually results in the creation of the GenSoFNN-AARS system. The interested reader may refer to [29] for a detailed discussion on the formalization of the AARS inference process, the extended modifications performed on AARS and the step-by-step mapping to define the computation process of the GenSoFNN-AARS memory model.

5 Glucose Metabolism: A Study of the Insulin Dynamics for Normoglycemia

Diabetes Mellitus, or commonly known as diabetes, is a chronic disease where the body is unable to properly and efficiently regulate the use and storage of glucose in the blood. This resulted in large perturbations of the plasma glucose level, leading to hyperglycemia (elevated glucose level) or hypoglycemia (depressed glucose level). Chronic hyperglycemia causes severe damage to the eyes, kidneys, nerves, heart and blood vessels of the patients [51] while severe hypoglycemia can deprive the body of energy and causes one to lose consciousness and can eventually become life threatening [52]. Currently, the treatment of diabetes is based on a two-pronged approach: strict dietary control and insulin medication. The objective of insulin therapy is to artificially re-create the insulin profiles of a diabetic patient and to regulate the blood glucose level within tight physiological limits (typically 60-110 mg/dl) [53]. Insulin can be administered subcutaneously, intravenously or peritoneally, and it can take the form of discrete insulin injections or continuous insulin delivery via an insulin pump [54]. Extensive studies on the advantages, disadvantages and peripheral issues regarding these insulin delivery approaches have been performed and reported in the literature [55, 56, 57].

The key constituent to a successful management of diabetes is essentially the capability to maintain long-term near-normoglycemia of the diabetic patient's glucose metabolic process. In line with this interest, the therapeutic effect of discrete insulin injections is not ideal for the treatment of diabetes as the regulation of the insulin enzyme is an open-looped process [58]. Continuous insulin infusion through an insulin pump, on the other hand, is a more viable approach to a better management of the patient's blood glucose level due to its controllable infusion rate [59]. The workings of such insulin pumps are algorithmic-driven, with an avalanche of techniques proposed, investigated and reported in the literature over the years [60, 61, 62]. Classical control methods and advanced algorithms using implicit knowledge or explicit models (empirical, fundamental, or "gray-box") of the diabetic patient have been studied and examined in [63, 64]. These included PID [65], nonlinear PID [66], Model Predictive Control (MPC) [67, 68, 69] and Internal Model Control (IMC) [70] based techniques. All such proposed methods required some form of modeling of the glucose metabolic process of the diabetic patient before a suitable control regime can be devised. However, the use of classical modeling techniques (data fitting, compartmentalized differential/difference equations, statistical or machine learning approaches etc) to describe the dynamics of the impaired diabetic metabolism process [71] generally results in a rigid system, which is neither dynamically evolving nor responsive to the inter- and intra-day variability of the patient's metabolic profile [72, 73].

The motivation of this work is therefore to employ the GenSoFNN-AARS network, which is a brain-inspired evolving learning memory model embedded with the formalized AARS inference process, to dynamically model the insulin profile of the glucose metabolism of a healthy human subject, so as to determine the insulin dynamics required to achieve homeostasis of the glucose metabolic process when perturbed by food intakes. The objective is to subsequently employ this insulin model as a reference to regulate and control the insulin infusion by means of an insulin pump to achieve long-term near-normoglycemia in the treatment of a Type-1 diabetic patient. Such an endeavor entails components of chance discovery as the effects of food intakes on the blood glucose level are delayed [74]. That is, the intelligent-based insulin regulatory mechanism of the insulin pump must be aware of and subsequently response to the risks of hyperglycemia (elevated blood glucose level) sometime after food intake has occurred. Such delays are dynamic and depended on the internal states (e.g. current glucose and insulin levels) of the glucose metabolic process.

5.1 Materials and Methods

The first step into constructing an insulin model of the healthy human glucose metabolic process is to determine the subject profile to be modeled. Due to the lack of real-life data and the logistical difficulties and ethical issues involving the collection of such data, a well-known web-based simulator known as *GlucoSim* [75] from the Illinois Institute of Technology (IIT) is employed to simulate a person subject to generate the blood glucose data that is needed for the construction of the insulin model. The objective of the study is to apply GenSoFNN-AARS, a brain-inspired computational model of the hippocampal memory system, to the modeling of the insulin dynamics for glucose metabolism of a healthy subject. A person profile for the simulated healthy subject is created as shown in Table 1.

The simulated healthy person, Subject A, is a typical middle-aged Asian male. His body mass index (BMI) is at 23.0, within the recommended range for Asian. Based on the person profile of Subject A, his recommended daily allowance (RDA) of carbohydrate intake from meals is computed using an applet from the website of the Health Promotion Board of Singapore [76]. According to his sex, age, weight and lifestyle, the recommended daily carbohydrate intake for subject A is approximately 346.9g per day. A total of 100 days of glucose metabolic data for Subject A is collected. Refer to [77] for the details on the data collection. Fig. 3 illustrates a sample output from GlucoSim for Subject A based on four assumed meals (i.e. breakfast, lunch, afternoon snack and dinner).

This output consists of six elements: blood glucose, blood insulin, intestinal glucose absorption rate, stomach glucose, total glucose uptake rate and liver glucose production rate of Subject A respectively over a simulated time period of 24 hours. The peaks in the stomach glucose subplot of Fig. 3 coincide with the timings of the assumed daily four meals (i.e. breakfast, lunch, afternoon snack and dinner) while those peaks in the intestinal glucose absorption rate subplot reflect a delay effect (response) of food intake on the blood glucose level of Subject A. The subplots of blood glucose and blood insulin illustrate the insulin-glucose regulatory mechanism in a healthy person such as Subject

Table 1. Person profile of the simulated healthy subject in the research project.

Profile name	Subject A
Sex	Male
Age	40 years old
Race	Asian
Weight	67 kg (147.71 lbs)
Height	1.70 m (5 ft 7 in)
BMI	23.0 (Recommended for Asian)
Lifestyle	Typical office worker with moderate physical activities such as walking briskly, leisure cycling and swimming.

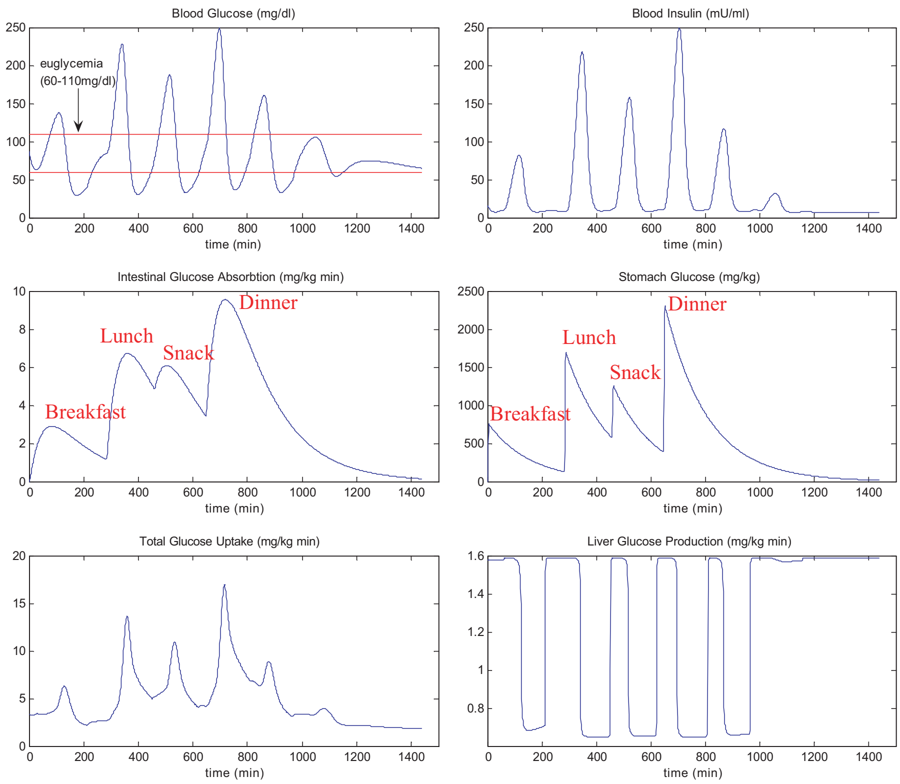

Fig. 3. Sample glucose metabolism data output from the GlucoSim simulator.

A and depict the insulin dynamics of the metabolic process when subjected to disturbances due to food intakes. Since the glucose metabolic process depends on its own current (and internal) states as well as exogenous inputs (or disturbances) due to food intakes, it is hypothesized that the insulin required to achieve homeostasis of the glucose metabolism at any given time is a non-linear function of prior food intakes and the historical traces of the insulin and blood glucose levels. To properly account for the effects of prior food ingestions to the blood glucose level, a historical window of six hours is adopted.

To resolve the variability issue in the number of meals (and hence number of inputs) taken within the previous six hours, a soft-windowing strategy is adopted to partition the six hours historical window and weighting function into three conceptual segments, namely: *Recent Window* (i.e. previous 1 hour), *Intermediate Past Window* (i.e. previous 1 to 3 hours) and *Long Ago Window* (i.e. previous 3 to 6 hours). The names of the segments are chosen to intuitively represent and reflect the human conceptual understanding and perception of time, resulting in only three food history inputs. Based on these

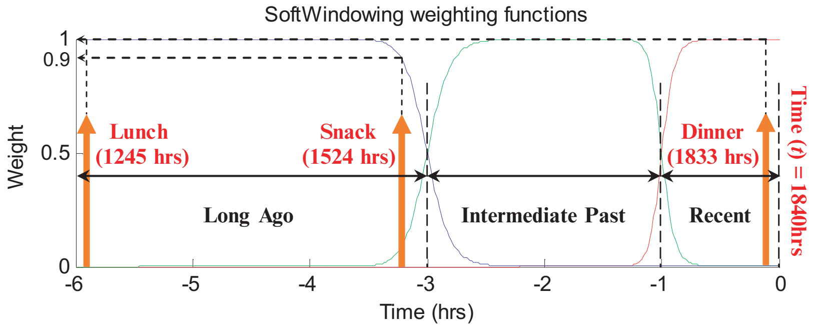

Fig. 4. Soft-windowing weighting functions to compute the carbohydrate content of meal(s) in the segmented windows of the 6-hours food history. In the figure, the current time is 1840 hrs and there are three instances of food intakes in the previous 6-hours; that is, lunch at 1245 hrs, afternoon snack at 1524 hrs and dinner at 1833 hrs respectively.

windows, three normalized weighting functions are introduced to compute the carbohydrate content of meal(s) taken within the *recent*, *intermediate past* or *long ago* periods. Fig. 4 depicts the weighting function for each of the segmented windows.

5.2 Results

Based on the formulated hypothesis and the preprocessed glucose data generated from GlucoSim, the brain-inspired GenSoFNN-AARS semantic memory system is employed to model the insulin profile of the glucose metabolic process of the healthy person Subject A. The collected data set is partitioned into two sets: 20 days of data as training data, and the remaining 80 days is used to test the performance of the network. The carbohydrate contents and the timings of the daily meals varied from day-to-day during the data collection phase using the simulator GlucoSim and are not fixed. This ensures that the GenSoFNN-AARS network is not being trained on a cyclical data set but employed to discover the inherent relationships between food intakes and the glucose metabolic process of a healthy person.

Figure 5 gives a 3-days snapshot of the *recall* accuracy (in-sample testing) of the GenSoFNN-AARS network, where the modeling performance of the system is evaluated by testing it against the training data. The evaluation of the GenSoFNN-AARS based insulin profile model is subsequently repeated using the remaining 80 days of data (hold-out sample). A 3-days snapshot of the *generalization* accuracy (out-of-sample testing) of the GenSoFNN-AARS network is depicted as Fig. 6.

Two performance indicators are used to quantify the modeling accuracy of the GenSoFNN-AARS learning memoy model on the perturbed insulin profile

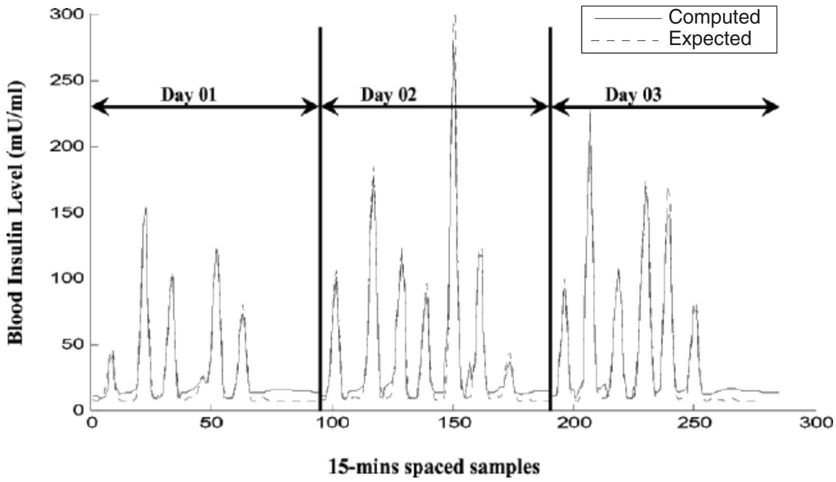

Fig. 5. Recall (in-sample testing) performance of the desired healthy insulin profile perturbed by food intakes using the GenSoFNN-AARS network.

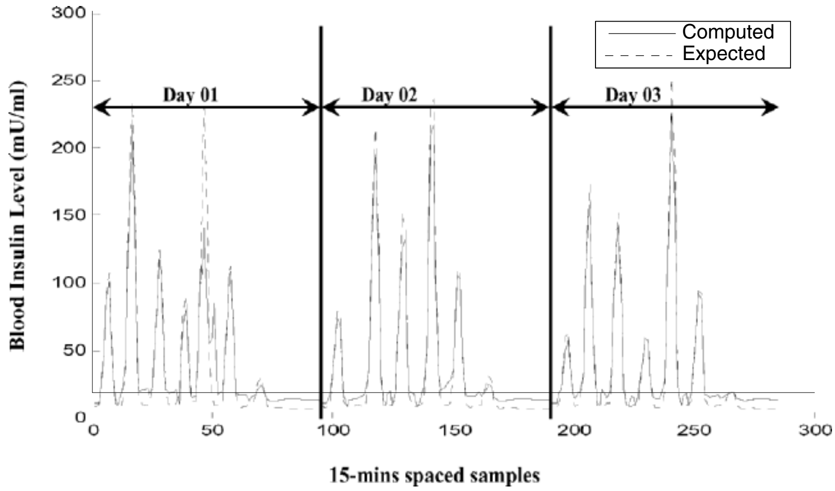

Fig. 6. Generalization (out-of-sample testing) performance of the desired healthy insulin profile perturbed by food intakes using the GenSoFNN-AARS network.

of the healthy person subject A. They are namely, the *root-mean-squared error* (RMSE) and the *Pearson correlation coefficient* (a statistical measure employed to verify the goodness-of-fit) between the desired and computed insulin profiles. The performances of the GenSoFNN-AARS network subjected to the recall and generalization evaluations are tabulated as Table 2.

From the plots of Fig. 5 and Fig. 6, as well as the performance indicators reported in Table 2, one can conclude that there is a moderately low level

Table 2. Simulation results of the blood insulin modeling using the GenSoFNN-AARS network.

Evaluation Mode	RMSE (mU/ml)	Pearson Correlation
Recall (in-sample testing)	6.5674	0.9938
Generalization (out-of-sample testing)	12.0200	0.9758

of degradation in the modeling performance of the GenSoFNN-AARS system as the evaluation emphasis shifted from the recall to the generalization capability of the system in determining the insulin requirement needed to achieve normoglycemia when the metabolic process is perturbed by food intakes. This is not surprising since generally, computational models tend to have poorer modeling and prediction performances to data samples that they have not encountered during their training phases. In spite of this fact, the estimated insulin profile computed by the GenSoFNN-AARS model in the generalization evaluation mode still managed to achieve a rather good-fit to the actual insulin requirements as indicated by a high correlation of 97.58% and a reasonable RMSE value of 12.02 mU/ml of blood insulin concentration. This indicates that the GenSoFNN-AARS memory model is able to efficiently capture the dynamics of the glucose metabolism process of a healthy person and to acquire the necessary knowledge to be able to identify and become aware of the risks of developing hyperglycemia (if left unattended to) after food ingestions, and to respond to such risks in a rationalized manner (i.e. to determine the required insulin dynamics to achieve normoglycemia after the perturbations).

6 Conclusions

This chapter proposes a neurocognitive approach to decision-making in chance discovery. Chance discovery refers to the identification of and to become aware of the phenomena (refer to as chances) that have significant impacts on the human decision-making process. There are two facets to chance discovery: the recognition of a chance event (which may be an opportunity or a risk) and chance management, where a rational response is required to address the designated phenomenon. In view of these two aspects of chance discovery, GenSoFNN-AARS, a brain-inspired hippocampal-like evolving semantic memory model embedded with an analogical reasoning based computation process, is employed to acquire the knowledge necessary for the recognition of chances in order to respond to them rationally. GenSoFNN-AARS is a functional model of the human brain's hippocampal subcortical structure and emulates the information handling and knowledge formation of its biological counterpart. Coupled with a highly formalized and intuitive analogical reasoning schema, the GenSoFNN-AARS memory model possesses the required capabilities to facilitate chance discovery and the subsequent decision-making process in a highly dynamic, complex and ill-defined environment. Such a brain-inspired engineering approach to the study of chance discovery is then validated by employing the GenSoFNN-AARS system to model the insulin profile of the glucose metabolic process of a healthy person perturbed by exogenous disturbances due to food intakes. The events of food ingestions can be perceived as risks leading to prolonged periods of elevated blood glucose level, a condition known as hyperglycemia, if little or no insulin is available to regulate the metabolism process, as in the case of Type-1 diabetic patients. The objective is therefore to use the GenSoFNN-AARS memory system to model and reconstruct the insulin profile required to achieve normoglycemia of the glucose metabolic process perturbed by food intakes. Simulation results have sufficiently demonstrated that the GenSoFNN-AARS system is able to capture the complex interacting relationships between food intakes, blood glucose level and the required blood insulin concentration to prevent hyperglycemia well. As future work, the GenSoFNN-AARS insulin model will be used as a reference model to develop an intelligent-based algorithmic driven insulin pump to treat Type-1 diabetes. These various research attempts are currently actively underway at the Centre for Computational Intelligence (C2i) located at the School of Computer Engineering in Nanyang Technological University, Singapore. The C2i lab undertakes intense research in the study and development of advanced brain-inspired learning memory architectures [78, 79, 80, 16] for the modeling of *complex*, *dynamic* and *non-linear* systems. These techniques have been successfully applied to numerous novel applications such as automated driving [81], signature forgery detection [82], gear control for the *continuous variable transmission* (CVT) system in an automobile [83], fingerprint verification [84], bank failure classification and early-warning system (EWS) [28], as well as in the biomedical engineering domain [85].

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Creative Marketing as Application of Chance Discovery

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1 What Marketers Using KeyGraph Have Been Waiting For

In the case of marketing, users of KeyGraph sold out new products, and made real business profits [1, 13]. Market researchers visualized the map of their market using KeyGraph, where nodes correspond to products and links correspond to co-occurrences between products in the basket data of customers. In this map, market researchers found a valuable new scenario of the life-style of customers who may buy the product across a wide range in the market, whereas previous methods of data-based marketing helped in identifying focused segments of customers and the scenarios to be obtained have been restricted to ones of customers in each local segment. As a result, users of KeyGraph for marketing successfully found promising new products, in a new desirable and realistic (i.e. possible to realize) scenario emerging from marketing discussions where scenarios of customers in various segments were exchanged. This realized hits of new products appearing on KeyGraph's bridges between islands, i.e. established customers.

In this Chapter, we go into an application of chance discovery using a touchable and visual data mining tool in the spiral process of human-machine collaboration with the interaction with the real business environment. A business application of this method, in choosing beneficial scenarios of producing and selling textile products in the real market, is presented. The results are evaluated by marketing experts on the effects on creative business decisions, and on the sales performance. The evaluation has been reflected to the next cycle of the process of chance discovery, and the company improved the sales performance.

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2 Chance Discovery Applied to Marketing

Traditional culture of companies sometimes disturbs from creative decisions to survive in the real dynamic market. In this sense, the techniques of *chance discovery* [2, 3, 4], i.e. the novel explanation of events significant for decisions, and of managing the discovered chances to be reflected to creative decisions and actions are commonly useful for company workers. In this paper, we executed a method of the discovery and the management of a chance, in Nittobo Inc., a company of textile production and sales. The method is composed of the three factors below. (2) and (3) work in the process of (1).

(1) The process of chance discovery called the Double Helix [2], where the concerns of a group of co-working marketers with new chances are deepened progressively.
(2) A visual and touchable market map, obtained by KeyGraph [3] applied to the market data and having real pieces of textile put on the map.
(3) A meeting of marketers as a place to create marketing scenarios.

We aim at achieving the following goals in marketing. First, we strengthen the attention of marketers to rare events, e.g. the purchase of a novel item by a customer, which may make a big impact on the market if marketers do not overlook the meaning of the event. A computer is not good at evaluating the significance of a rare/novel event, because the causes of a rare event tend to be unknown, and because unknown causes are hardly reflected explicitly to the recorded data.

There is a possibility that those hidden causal events have been appearing in the past experiences of marketers, because they continuously keep touch with the market. However, some tacit experiments cannot be expressed in a speech or a written document. In this aspect, the externalization of the marketer's tacit experiences is required.

However, if a marketer relies only on his/her own experiences, there is a risk of ignoring essential behaviors of customers because one's temporary concern focuses one's recollection of past experiences on a very small part of the market. Therefore, a map of the market, where the positions of various customer-behaviors are visualized, is required for externalizing the expert experiences without strong bias in the awareness of chances. Here, KeyGraph [3] visualizing the *islands* and *bridges* (explained in later sections) in the market is shown to marketers, as the map of the market. In order to stimulate the recollection of marketers, we further reinforced KeyGraph into a new device called a *touchable* KeyGraph on which real pieces of textile items are put.

Second, we kept marketers motivated to discover and manage chances. Generally speaking, persuasion, i.e., getting the consensus of the members of a company on a certain proposal, is difficult if the proposal is based on a scenario considering a rare event. This is because the scenario in the future of a rare event is uncertain, because human has seldom learned about it, and tends to be felt untrustworthy. A way to encourage members to work for chances is to have them share the concerns with new chances, have them propose and choose scenarios for themselves, and allow them to work on their own decisions. In this paper, we use the effect of group meeting, starting from concern-sharing and exchanging scenarios on the map of market with KeyGraph, for realizing continuous concerns.

In the Double Helix (DH, hereafter) process of chance discovery [2], a computer aids in deepening human's concern with a chance, by visualizing the interaction between human and the environment, and between human and human. Here, humans and an automated data mining system collaborate, each processing spirally toward the creation of the scenarios of future events and future actions, as in Fig. 1.

The DH model has two helical sub-processes. One is the process of human progressing to deeper concern with chances. The other helix is of computer(s), receiving and mining the data (DM in short). In Fig. 1, the wide road depicts the process of human(s), and the dotted curve depicts the process of computer. Between these two helixes, interactions below occur following the thin arrows in Fig. 1.

First, the object (external) data, that is the data from user's environment, is collected reflecting the user's concern with the target domain, and put in the computer. The mining result from the object data (DM-b) is then reflected to user's understanding of the chance. The subject (internal) data, the text record of users' thoughts and communications about future scenarios, is then put into the computer. The mining result from the subject data (DM-a) is shown to the user her/himself, for enabling to clarify the future scenario in

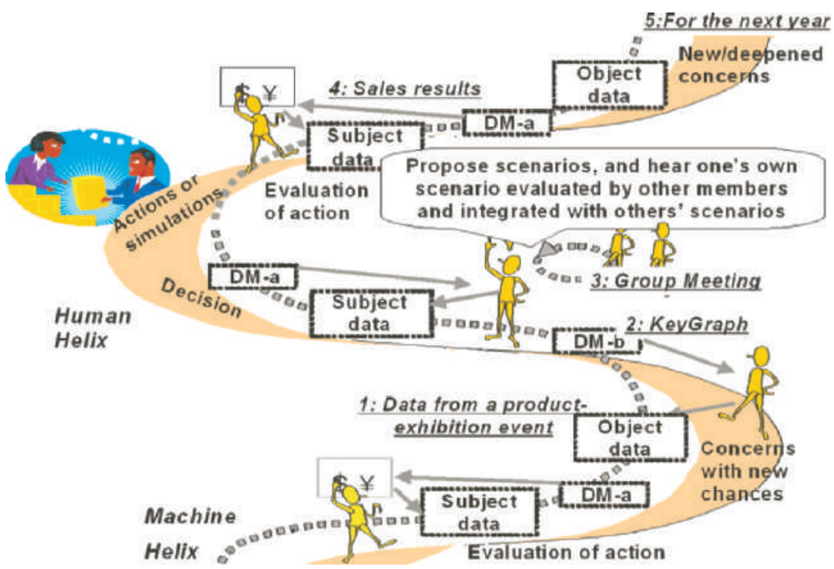

Fig. 1. The double helix (DH) process applied to marketing.

her/his own mind. This is essential because users tends to overlook their own ideas if the thoughts are not recorded. Even a raw subject data, presented without being processed by data mining, sometimes works for this purpose. The name "double-helix" means the parallel running of the pair of helixes (spiral processes) due to monitoring the subject data.

The first step in the execution of double helix in this paper was to have the marketing staffs be concerned with discovering chances. Extending the words "a chances favors a prepared mind" by Louis Pasteur to the mind of a group of members, it is essential to share the concern with chances by the members co-working in the company. For realizing this prepared mind is, we first educated marketing staffs of Nittobo Inc., by explaining the potential value of rare events in the dynamic market. Then, for having them keep the concern, we introduced scenario communication in the group of marketing. Here, members propose scenarios considering both frequent and rare behaviors of customers, and a new scenario may emerge and lead the company to success. If a proposal has a risk to make a failure, the proposal can be stopped in the meeting. After all, the survived proposals will be reflected to the action of the company, supported by the responsibility of the group. This makes the concern keep going for each member.

3 Preliminary Comparisons of Visual Data-Mining Tools:

3.1 Visual data-mining Tools for market maps

After acquiring the concern, in the DH process, the object data, matching with the marketers' concerns to satisfy the demands of customers, was visualized by data mining tools. Here, we had members evaluate three data-mining tools for the same data of customers' orders. That is, each part of the object data was in the form of Fig. 2, recording the textile selections of a single customer from 400 sample-items exhibited in a textile exhibition event of Nittobo Inc. The data of orders from all customers was taken as the object data. For externalizing tacit experiences of marketers, the data mining tool should show the following parts of the market.

(1) Islands, each of which corresponds to a set of items for satisfying an established desire of customers. These islands show well-known parts of the market.

<Customer P's choice>
    Item X: cotton, 4way, ... (features of item X)
    Item Y: cotton, 1way, ... (features of item Y)
    Item Z: rayon, 4way, ... (features of item Z)
    ...
    ...

Fig. 2. The data of item-set in the order-card of one customer.

(2) Bridges between islands in (1), aiding user's understanding of scenarios of customers' dynamic behaviors, i.e., the shift from a certain island to another. In comparison to existing marketing methods assuming each customer stays in one island, we seek triggers to activate customers to desire new attractive islands.

Clustering methods such as bottom-up [5, 6], hierarchical [7], and strategies to cut bridges [8] do not fit because they hide bridges. In Nittobo, the marketing staffs compared three tools here, decision tree [9], correspondence analysis [10], and KeyGraph [3], because these were regarded as satisfying (1) and (2) above.

In a decision tree, a group of items of similar features were depicted as one node, and the hierarchical relations between nodes were shown as a tree as in Fig. 3. This structure was obtained using the C4.5 algorithm, on the features of items in the data of order-cards (as Fig. 2). Users said a node in a higher level can be regarded as a bridge in (2) above.

In the correspondence analysis, items and companies appearing in the same order-cards such as Fig. 2 were located near to each other in the 2D visualization as in Fig. 4. For example, CS3060HJ and CS4100NHJ in the circle of "1) 4 way casual" in Fig. 4 often appeared in the same order-card. That is, many customers ordered these two in one set.

Users of correspondence analysis said they recognized a group of neighboring items as an island and the nodes located between islands as a bridge. On the other hand, KeyGraph shows frequent items in black nodes as in Fig. 5, and connects a pair of black nodes by solid black lines if they correspond to a pair of items appearing frequently in the same order-card. Islands are here obtained as connected graphs of solid lines. Then KeyGraph shows rare items appearing with items from multiple islands, as red nodes. The dotted lines between red nodes and islands show bridges, and an overall view of KeyGraph is regarded as the map of the market.

In order to choose one (or more if useful) tool from the three, the marketing team members looked at the results, and evaluated the performance of each tool. A group of three users, representing the marketing section, were selected as the evaluator of the outputs of each tool because these satisfied the

```
price > 760
| particularity = HMS: high (3.41)
| particularity = MMO
| | construction = DOUBLECLOTH: high (2.49)
| particularity = standard
| | width(cm) > 113
| | | width(cm) <= 115
| | | | construction = SATTEN: high (2.49)
```

Fig. 3. A decision tree, having learned the class of frequently bought items by C4.5.

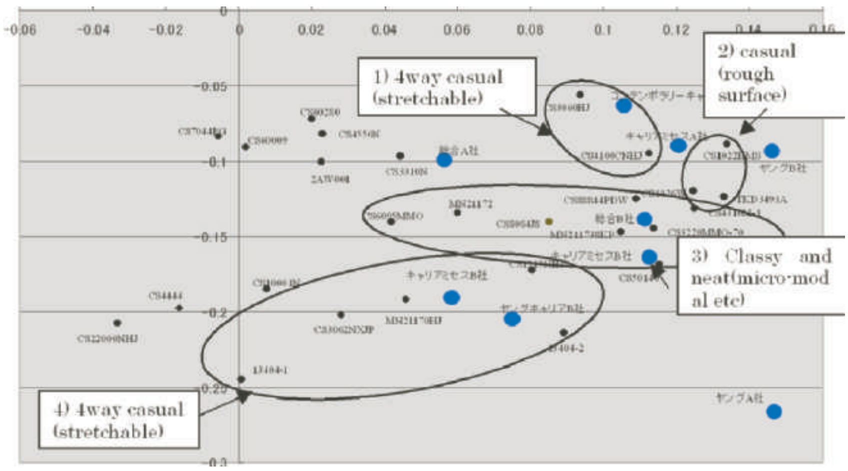

Fig. 4. A result of correspondence analysis. The interpretations as in the ellipses and labels 1) to 4) were made by the subject users.

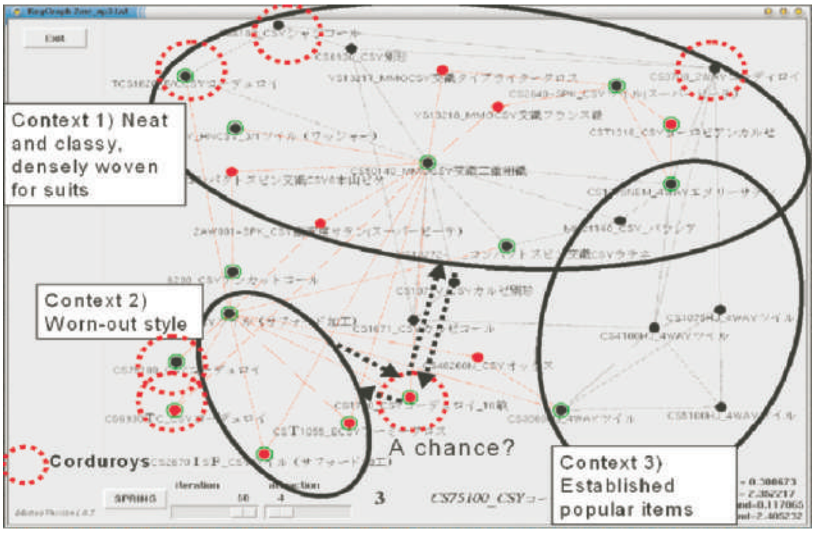

Fig. 5. The result of KeyGraph for the autumnal exhibition, 2002.

condition that the user should have rich experience of the market enough to understand all items in the result. This is because the performance of chance discovery means how good decisions can be obtained in the group discussions, in the scenario-proposal step in double helix. An essential evaluation of chance discovery in a group of people is how well the novel proposals achieve consensus about new futures actions, among leading experts, not how precisely the output corresponded to the past. In this case, the three people were the selected staffs with the highest expertise in the company.

3.2 The scenarios obtained

Let us show a few scenarios obtained by using each tool. Let us note the customers are companies who produce clothes from the textile materials sold from Nittobo.

[Abstract of scenarios based on the decision trees]

- Many customers prefer to buy expensive items, because they like to produce new types of clothes to attract new consumers.
- Many customers prefer to mix double-woven (a way of weaving) and satin materials.
- Customers tend to buy more denims than in the past.

[Abstract of scenarios based on correspondence analysis]

- Customers tend to belong to one of the two major islands of preference, i.e., to produce neat style clothes, or worn-out style clothes.
- Customer A prefers materials for classy clothes.
- Customer B prefers 4WAY (a way of weaving) materials, and produce clothes for ladies.

[Abstract of scenarios based on KeyGraph]

- Many customers buy items in one of the two islands, i.e., for producing neat style, or worn-out style clothes.
- The nodes on bridges are rare items, and tend to be a higher-cost version of the items in the islands. It may be good to sell a textile and its high-cost version in one set.

3.3 Comparison of tools' performance

The evaluation criteria here are the ability of tools to aid users' creativity in developing scenarios. In Table 1, the criteria 1) means the number of items in

Table 1. Comparison of three miners

	Correspondence	Trees	KeyGraph
1) The rate of items with explicit demands	56%	60%	58%
2) The rate of items of latent demands	1%	3.3%	7.5%
3) The number of feasible new future scenarios	0	1	4
4) The number of feasible scenarios including bridges	0	0	3
5) The number of scenarios to change global strategies	0	1	3

the output of the tool, which subjects regarded as items belonging to islands, i.e., demands which are already popular, divided by the number of all items appearing in the output. These items were marked by the subjects' annotations such as the circular frames in Fig. 4 and Fig. 5. 2) is the number of items in the output, matching customer's demands but not noticed before looking at the map, divided by the number of all items in the output. 3) is the number of proposed scenarios, which are feasible (possible to be executed in the real business) but not proposed before. 4) is the number of scenarios including the items of 2), amongst the scenarios in 3). 5) is the number of scenarios, which can be expected to make a radical innovation in the marketing strategy of the company.

According to these results, they concluded KeyGraph is the most suitable for creative business. That is, they found the demands of customers they had never noticed, and these findings lead to thinking about new scenarios of customers. On the other hand, understanding the established demands was possible also by other methods in the table. For satisfying customers with stable supply of items which were previously popular, tools with high values of criteria 1) are useful.

For satisfying each customer by one-to-one marketing with the understanding of the feature of each customer, the feature of correspondence analysis, to clarify the positions of customers in the market map of product items, was helpful. However, this is possible in KeyGraph, if the first line of Fig. 2 is included in the data to input to KeyGraph.

In order to back up the preference of KeyGraph on the subjects' evaluation, we made an interview test of these three methods the a priori method for learning association rules [19], for the sales data in a supermarket, because we found a larger number of people who understand the items, than for the data of Nittobo' s customers choices. For example, the data on one-time purchase by a customer is like <Customer Q's choice> : apple, tomato, radish, wine.

Collecting these data from all customers for one year, we obtained the results of the four tools, for the data collection for different kinds of customers ("women of 50 years old" "men of 30 years old" etc). For example, KeyGraph showed a figure like Fig. 6, where each node corresponds to a food item. Then, a scenario such as "customers usually buy foods for breakfast, but can also begin to buy for dinner if they buy small dry fishes" was obtained.

The results of the four tools are in Table 2. The association rules to be shown were set to those of both high-support and low-support rules (i.e., support value from 0 to 1), of high confidence (confidence of 0.7 or more). This is because the link in KeyGraph connecting an item X on a bridge, and an item Y representing an island (i.e., of the highest co-occurrence with X in the island) corresponded to rule X -> Y, of confidence of more than 0.7 and of support less than 0.015. On the other hand, the rule X -> Y for X and Y both included in the same island in KeyGraph had support values of more than 0.02. For showing association rules without relying on KeyGraph, we had to show all rules of confidence larger than 0.7. As a result, we showed

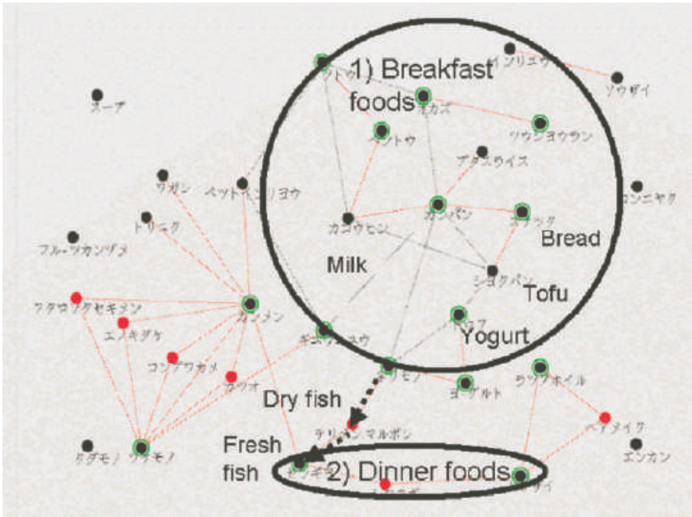

Fig. 6. A result of KeyGraph for a supermarket data.

Table 2. The performance of data mining tools, for supermarket-store sales data. For each method, a group of 6 subjects were assigned as evaluators. 20 results corresponding to 20 kinds of customers in the store of one year, were obtained, and each result was evaluated by its assigned evaluators. The numbers out of and in the brackets are the average and the standard deviations respectively

	Corresp.	Trees	KeyGraph	Association rules
1) The rate of items with explicit demands	46.3% (8%)	50.3% (7%)	48.6% (10%)	61.3% (13%)
2) The rate of items of latent demands	0.8% (0.2%)	2.4% (0.4%)	4.3% (0.6%)	2.4% (0.7%)
3) The num. of feasible new future scenarios	0.7 (0.1)	1.3 (0.3)	3.8 (0.9)	0.6 (0.3)
4) The num. of feasible scenarios including bridges	0.7 (0.3)	1.0 (0.2)	2.1 (1.0)	0.3 (0.1)
5) The num. of scenarios to change global strategies	0.6 (0.3)	1.0 (0.1)	2.1 (0.7)	0.3 (0.3)

36 association rules in average per dataset, in the order of confidence values, from which subjects hardly find the scenarios, i.e., a set of rules to form a meaningful sequence of events. Here, the number of items in criteria 1) and 2) in Table 2 means the items appearing in these lists of association rules.

In a decision tree, the hierarchy was hard to understand. When subjects understood the structure, the result did not go beyond their established understanding of the market, they had in mind before seeing the tree. This is useful for proposing to continue the established current promotions, but not useful for making a new trend in the market.

Correspondence analysis worked in finding products suiting each customer and customers in each island, because it makes clear the position of each island of customers and products. However, new scenarios for promoting new products were not made. Although the interpretation of the horizontal and the vertical axes are said to be essential in this tool, no interpretation of any axis X or Y was obtained.

On the other hand, KeyGraph clarified the overall structure of the market, including the already-popular and novel/rare items. The nodes to be presented are focused onto a small number, but the evaluators could propose scenarios of customer behaviors. The group members integrated their expert knowledge with the result of KeyGraph, and achieved consensus on strategies for developing and promoting products to satisfy latent demands of customers.

4 Scenario Communications with Touchable KeyGraph

4.1 Touchable KeyGraph

As in Table 1 and Table 2, KeyGraph was the most useful for the purpose of creative proposals for product developments and promotions. However, the connections tended to be dense for dealing with a large number of items members wanted to see. This made it hard to understand the islands and bridges at a glance. As a result, the members of Nittobo made pieces of textile samples to put on the printed output of KeyGraph as in Fig. 7, because this appeals to both the touching sense and the vision of user. From this touchable KeyGraph,

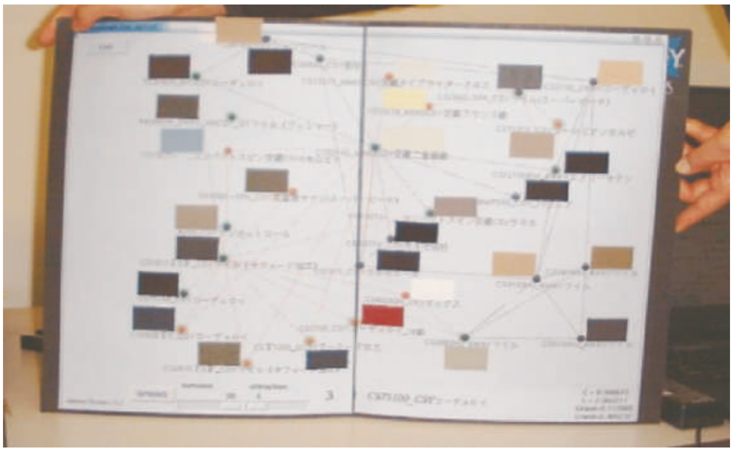

Fig. 7. The touchable KeyGraph, i.e., with attached textile pieces.

members recollected established fashions corresponding to the islands of market, and new scenarios of consumer life tripping from/to islands island via bridges. Items for the bridge nodes were even not shown in the other tools due to their rare occurrences.

4.2 Consensus, decision, and actions from scenario meetings with touchable KeyGraph

In the DH process in Fig. 1, communications in a group meeting help chance discovery in two senses in the step of proposing scenarios, as well as in the acquisition of concerns with chances. First, if one has somebody to talk to, the words will be fed back to oneself after being filtered out keeping only noteworthy scenarios. In other words, a meeting returns a scenario to the participant who proposed it, with an objective comment of evaluation. This worked as a supply system of subject-data to each member of the group. Second, human communications create scenarios by combining proposed scenarios. For example, let a member in the group be accustomed to the context of Scenario 1 below:

Scenario 1: *Business people wear neat suits made of densely woven textile, but seek more casual clothes to feel relaxed.*

In Scenario 1, clothes from the textiles near the label "Context 1" in Fig. 5 were worn. Another member may be accustomed to Context 2, corresponding to Scenario 2 below.

Scenario 2: *Young people wear casual clothes usually, but sometimes seek neater ones.*

If these two notice a new item marked "a chance?" between Context 1 and Context 2, this can be discussed because they find the item as the bridge between themselves. Then they find the "chance" item is a material of clothes for business in Scenario 1, and also for youth in Scenario 2.

As a result, the two members can create a scenario that business people wear neat suits, but seek clothes made of the textile of "a chance?" and get relaxed like young people on holidays. The communication in a group of people knowing different environmental contexts can thus lead to creation of and consensus with a new scenario giving new meaning to a chance item.

An essence of double helix is that the subject data is shown to the meeting members. The house-wives in [4], however, did not look at their past opinions. As a result, they discarded proposed scenarios on facing trivial conflicts between participants, in spite of the potential usefulness of the scenarios. For overcoming this problem, we may visualize scenarios in ways as:

(a) Writing and reviewing the scenarios on the black board
(b) Visualizing KeyGraph for a document collecting all scenarios

We chose (a) here. It might be ideal if (b) is available, but this is not realistic yet in a meeting of a company which progresses too fast to look at the output of KeyGraph each time in conversations.

5 The Evaluations on Business Fruits

5.1 The difficulty in the evaluation of chance discovery

Methods for predicting rare events have been presented in the literature [11, 12, 13], showing their high performance. For example, the data mining tool for predicting rare event has been evaluated finely in [12], considering the recall and the precision, i.e., the ratio of events correctly classified to its belonging rare class by the tool divided by the real number of events of the rare class (recall) and by the number of events classified to the rare class by the tool (precision).

On the other hand, in chance discovery, the event desired to be discovered is not necessarily rare, but there are more difficult problems than rarity. First, we do not know in advance what event, or, more severely, what kind of event should be extracted. This does not only mean to we cannot make a supervised learning, but also we have to give up to employ the method of clustering, because we need to find bridges between clusters we call islands. If we do clustering, human expert can check the belonging of each item to the cluster of its similar items, based on his/her established sense of similarity. However, in chance discovery, human cannot say "this is good" only because it matches his established sense. Rather, an item looking like a violation of established rules or senses should be evaluated on new criteria.

Paradoxically speaking, suppose a pattern be matching 90% of the past events, and another matching 99%, the decision maker may have to select the former because there is a chance of a new decision from the exceptional event violating the pattern. In this sense, accuracy is not a suitable criterion for evaluating a system of chance discovery.

More fundamental difficulty lies in the point that the scenario of creating the new future, for winning the business race against rivals, should be to make oneself different from other companies. For this purpose, in most cases one have to make a future scenario different from a scenario of events in the past, assuming most rivals go in the way similar to the past, or for satisfying the existing desires of customers. A company must at least satisfy those existing desires as rivals do, but also must create differentiable features.

Our strategy for chance discovery is to develop and execute the overall process, supported by the tools. Thus, we do not reduce the evaluation of the performance of a company to the accuracy of tools, which are positioned as components of the process, but evaluated the result of the overall activities. In this point of view, here we evaluate the method of chance discovery by looking at the new fruits of business, achieved based on the chances discovered.

5.2 The future of "a Chance?" node in the example

The chance node, i.e., the node of "a chance?" in Fig. 5, between the cluster of "neat and classy" and the one of "worn-out style" made an outstanding success as follows.

In the autumnal exhibition of textiles in 2002, Nittobo exhibited textile samples to be used in the next winter. Here, the number of orders of the item of the chance node was ranked to the 52^{nd} best of the 400 items exhibited.

Then, from the step of scenario communication with sharing Fig. 7, the chance node has got interpreted to be a potential trigger to combine the two scenarios corresponding to the two islands, i.e., the one of people accustomed to neat suits and the other of people accustomed to worn-out style casual wears. This combination of scenarios lead the marketers to agreeing with the new scenarios, i.e., the scenario that suit users will also buy worn-out, and the other that worn-out users will also buy suits if they buy the chance item.

By selling the textiles in the two islands and the chance node in one set, customers responded to the new scenarios underlying this set of items. The response of the customers was that the corduroy of the chance node rose up to be the 13^{th} best, in the ranking list of real sales volume in winter among the 800 items sold from Nittobo. It is very rare that a new product comes into a rank higher than the 30^{th}. Furthermore, the rise from the 52^{nd} best of the 400 items in the exhibition to the 13^{th} of the 800 items in the sales means the presentation of a new scenario of consumer behaviors stimulated the latent desire of consumers for introducing such a scenario in their way of living.

5.3 The effects of bridges

Here, let us see if the effect of novel awareness of scenarios of customers-behaviors, by the aid of chance discovery, can be generalized. We looked at the results for the five seasons, i.e., 2002 spring-to-summer (SS), 2002 autumn-to-winder (AW), 2003SS, 2003AW, and 2004SS. In each season, a result of KeyGraph was presented in which 30 nodes in islands and about 10 nodes on bridges were shown. In total, they had 240 nodes in islands and 32 on bridges.

As the examples of textiles in Table 4, the rank of sales volumes of new products corresponding to discovered chances nodes, were higher than their frequency to be ordered in the exhibition. This means the effect of sales strategy obtained from the scenario communication. The sales rank of new products, i.e., products exhibited in the latest exhibition event, has been ranging between the 100^{th} and the 200^{th} of the 800 items sold. On the other hand,

Table 3. Products commercialized, and their sales ranking

Product	Rank in exhibition	Rank in sales
CS6930TC	52^{nd}/400 items	13^{th}/800 items
2AW001SPK	30^{th}/400 items	28^{th}/800 items
CS40260N	65^{th}/400 items	24^{th}/800 items
CS6930TC	52^{nd}/400 items	33^{rd}/800 items

Table 4. The commercialization of items on red nodes (AW: Autumn and Winter, SS: Spring and Summer)

Season	Commercialization rate
2002SS	49%
2002AW	50%
2003SS	57%
2003AW	43%
2004SS	69%

all the items on the bridges in KeyGraph, which were commercialized (promoted and sold after exhibition) after the introduction of the process of chance discovery using KeyGraph, ranked higher than 50^{th}.

5.4 The growth in the commercialization rate

Commercialization rate is an established business criterion, defined as the number of items which were decided to be thrown in the real sales, considering the performance in a test sales for a period. In average, Nittobo shows 400 items in an exhibition, and items ordered from customers in the period of after the exhibition are commercialized.

In average, 20% of the exhibited items have been commercialized. On the other hand, the commercialization rate of items in Fig. 5 was 60%. The average commercialization rate of black nodes (established items) appearing in the scenarios going across bridges was 68%. Another remarkable result was that the red nodes got 49% of commercialization rate in the summer of 2002, in spite of the much less frequency than black nodes. In the continuation of double helix, since 2002, the commercialization rate of chance nodes has been kept high, and mostly increasing:

We can point out the rapid increase of commercialization rate in 2004, after the decrease in the autumn of 2003. In this way, the marketing team has been finding triggers to improve their sales, and reflecting their new concerns in the real market to the exhibitions in the next season. For example, in the presentation of textile samples, they now also show clothes produced from the textiles they sell. Here, they are introducing the way of collecting data about customer's demands, reflecting their communications with customers about the scenario of producing and selling clothes from the textiles of Nittobo. Thus, they are increasing the business performance, as represented by the 69% commercialization rate in Table 4, by progressing on the DH process.

6 The Prepared Mind of Individual Marketer and Chance Discovery

By the previous section we showed how the education, the computer-aided communication enforces chance discovery. A problem still remains however: There should be someone in the team, who noticed the significance of the chance-item. What happened to this marketer? Is it some special talent that enabled him to catch the chance?

We are obtaining a tentative but an encouraging answer to this question, by the following preliminary experiment. We had a head-mount eye camera as in Fig. 8, worn by the subject who is a marketer who sometimes noticed the significance of rare but significant items. The subject looked at the output of KeyGraph as in Fig. 9, which is the result for knit products for summer. Similarly to Fig. 7, small pieces of textile products were put on the printed figure, and the subject was instructed to talk about the scenarios coming up to his mind during the experiment of 10 minutes.

We had a hypothesis in advance of this experiment: As in Fig. 10, we expected the eyes may move in the following steps:

(1) The eyes catch some queer point on the figure.
(2) The eyes move quickly to catch the overview of relations among items (saccard), around the focal item at the point in (1).

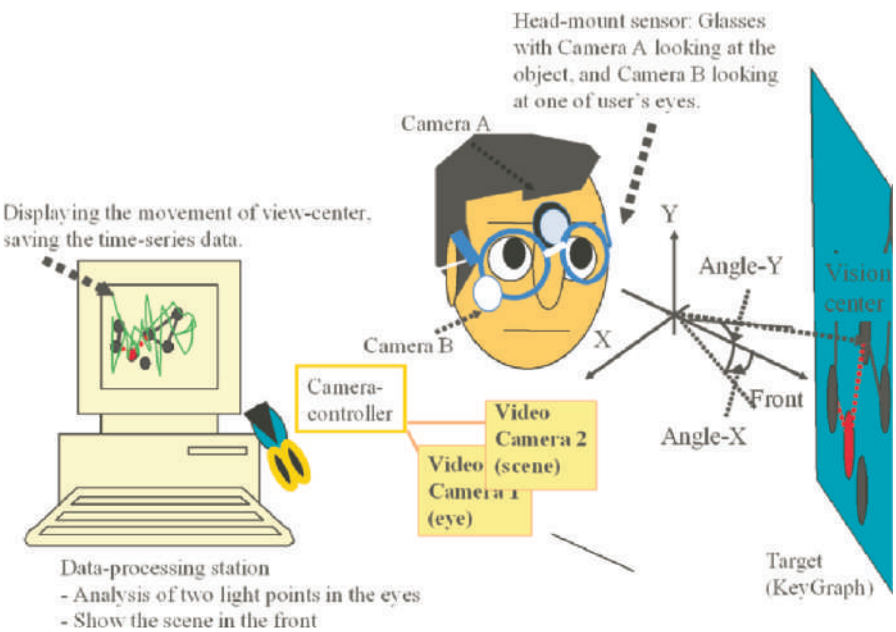

Fig. 8. The tool kit for the experiment of eye-movements over the figure of KeyGraph

Fig. 9. The KeyGraph used for the eye-movement experiment

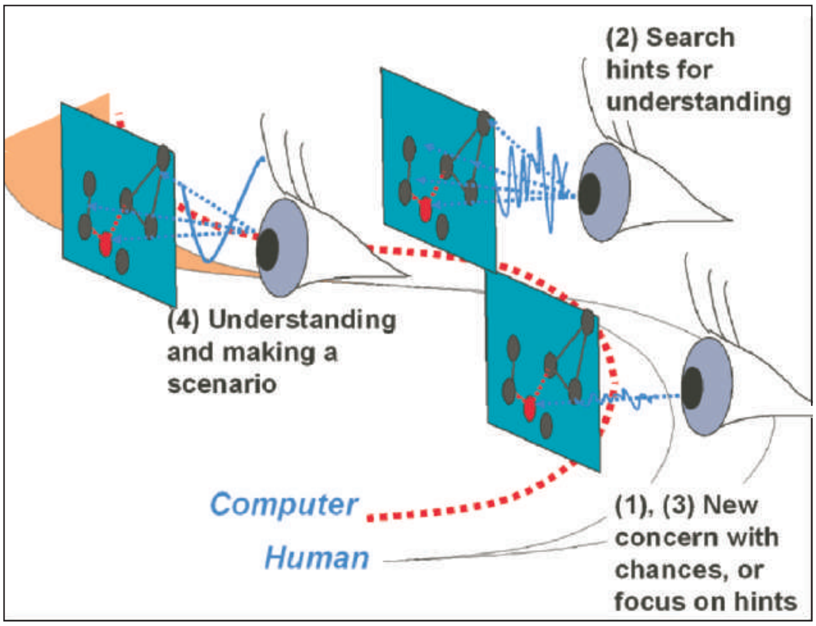

Fig. 10. The eye-movement for Chance Discovery

Fig. 11. The scenario obtained after the eye-movement: This lead to another success in the marketing.

(3) The subject understands the underlying scenario, and, as a result, the eye movement converges to following the most meaningful curve corresponding to a meaningful sequence of events including the focal item.

Our hypothesis has got supported by the subject for two cases. Note that we can not have so many subjects who do cooperation to our publication of individual marketer's awareness. For this reason, we have just two cases for one subject. Reader may say the following claim is not significant at all. However, the facts obtained were noteworthy:

1) For the ten minutes, the subject looked at all the items on the map carefully.
2) The subject payed strong attention to three of the items on the map, i.e., the eyes stopped more than 1 second at each of the three items.
3) He talked all the time about his thought, and it was clear that he could not create a marketing scenario for two of the three items in 2). The eyes stopped as in Step (1) above at these two items, and make a fast swinging (period: 30 to 50 ms) as in Step (2). However, Step (3) did not come out: The eyes jumped to other part of the map.
4) For the last one of the three items in 2), he made a new scenario to sell the product, as illustrated in Fig. 11. At this item, the eyes stopped as in Step (1), had a fast swinging of Step (2), and Step (3) occurred: The eyes moved slowly between the two islands via the small piece of textile depicted by the small circle in Fig. 11. The upper island was a group of textiles for producing a suit and formal under ware, whereas the lower island was a group of colorful items used for producing young people's casual clothes to go out playing with. He thought the marked item is colorful enough for casual cloth, but so thin that it was only for making under ware. Finally he concluded that the cloth should be thickened enough for making casual

clothes. This scenario was reflected to the sales action of the company, and the result was the sales growth of the marked item.

7 Conclusions

The process of three steps, (1) the activation of concern by the education about chance discovery, (2) the selection of the object data and the data mining tool, and (3) the scenario communication in the group of decision makers with looking at the market map, was shown to realize chance discovery.

Here, touchable KeyGraph was invented and positioned as a tool for visualizing the market map. The overall process was evaluated on the real business fruit, i.e., the performance of sales on the chances discovered by the presented method. The cognitive tendency of human to ignore rear events in the understanding of causality [14] is here overcome in the real application. It has been recognized that the 2D data/text visualization works for aiding the creativity of a group [15, 16], but our work reached beyond visualization by including touchable interface and the process of social chance-discovery and social chance-management.

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Extracting High Quality Scenario for Consensus on Specifications of New Products

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Summary. 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 about customers' requirements, 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.

1 Introduction

Manufacturing companies are expected to have the members develop new products responding to customers' requirements. For this purpose, designing scenarios of behaviors of forthcoming products and their users is regarded as a key effort [1, 2, 3]. Previously, various technologies came to assist the process of chance discovery [4]. As shown in the literature [4, 5], the process of chance discovery and scenario design are in a mutually-involving relationship. For 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 in the output of KeyGraph, the user is supposed to understand the meaningful scenarios from the sequence of events, by connecting closely located items. Some successful cases have been presented [7, 8] in the domain of marketing. For example, marketers in a textile manufacturing company achieved the consensus to duplicate the production quantity of a new product

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they detected as a "chance product" by creating scenarios of the product's future in the market, based on KeyGraph applied for the data on their market. They increased the sales of the focused product as a result.

However, a critical problem has been remaining if the method is applied to the design and development of products, i.e., the stage before selling. That is, the working members of a manufacturing company are born and bred in different contexts: Engineers and designers graduated from engineering schools, and marketers may be from business /management schools. These people should talk for developing a new product. Thus, the vocabulary gap among these people causes a deadlock, i.e., creative ideas of developers and designers are sometimes misunderstood and can not contribute to the corporate decision. In turn, the proposals from marketers do not move designers or developers.

In this chapter, we present and validate a method for aiding the cross-disciplinary communication to achieve a decision to design a product. This is 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 a given data-set are embedded to the visual result of KeyGraph applied to their business reports about customers' requirements, manually 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 behaviors were extracted, and finally produced new products by connecting islands via items lying between islands in KeyGraph.

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 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 of the manufacturer producing the CCD surface inspector. Although technical sales people have been collecting and bringing reports about customers' requirements, those reports were the brain children of technical experts - i.e., all written in specific engineering terms. Even though the reports included call (telephone from customers) reports and test reports (free text on the communication between customers and the technical sales people), no new practical ideas for product innovations have been extracted in the company we deal with here. To this problem, we adopt the following procedure in this chapter. Here the tool is Pictorial KeyGraph, that is KeyGraph with a new function to embed pictures of real entities corresponding to items (i.e., words) in the reports.

[The Design Communication with Pictorial KeyGraph]

1) Visualize the textual dataset D, obtained by putting all previous reports of developer-user communication in one file, by KeyGraph.
2) Do communication about considerable scenarios with looking at the graph shown in 1). This communication goes in a way as:
   2-1) Each participant presents a scenario about the product behaviors.
   2-2) If there is a hard item to understand, on KeyGraph, 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 the opinions of 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 expected advantage is that the vocabulary gap is filled by the pictures which urge the participants' sharing of imagination. In the reminder, we go as follows. In Section 3, the outline of KeyGraph is introduced (reader is referred to Chapter 5 of this book for details). Then, Pictorial KeyGraph is presented with showing the operation on Polaris. Then, in Section 4, we show how we applied this tool for the data-based design communication. Finally, in Section 5 we show the real-business result we obtained, by this tool and the process of the participants. This evaluation is subjective and uncontrolled, in that we see the effects of the presented method to support human's creativity in the real process of design, not on any precision/accuracy measures. This is an ideal way for the 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 caused by the 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, 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:

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

For data D, KeyGraph runs as follows, where $M0$, $M1$, $M2$ are to be fixed by user:

KeyGraph-1: Clusters of frequent items (events among the $M0$ most frequent in D) are made, by connecting the $M1$ highest co-occurrence pairs. Each cluster is called an *island*. Items in islands (e.g., "a1" or "a4" in Eq. (1)) are depicted with black nodes, and each pair of these items occurring often in the same line are 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, where weak links are cut and form meaningful islands corresponding to established concepts.

KeyGraph-2: Items which may not be so frequent as the nodes in islands, but whose co-occurrence with more than one islands are among the $M2$ highest item-island co-occurrence, e.g., "a10" in Eq. (1), 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 line. 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 color (e.g. red or white). 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. 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 is a sequential appearance of islands via rare events as depicted by the red bridging nodes.

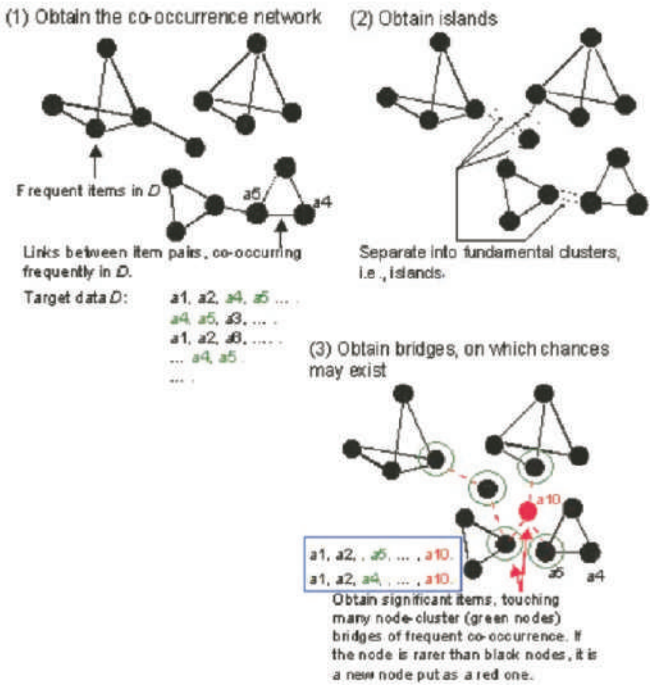

Fig. 1. The procedure of KeyGraph.

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.

3.2 Pictorial KeyGraph

Pictorial KeyGraph has been born, with a function to embed realistic images onto the graph, succeeding the experience of embedding real products onto the graph in the textile company. Here, we introduce Pictorial KeyGraph, where nodes are replaced by pictures of corresponding real entities in data set D. This placement is executed by user's drugging picture icons, from the PC desktop to the output window of KeyGraph (See Fig. 2). This is a full digitalization of putting real entities as done by workers on textile, at the sacrifice of the merit of touch-sensing in embedding real products.

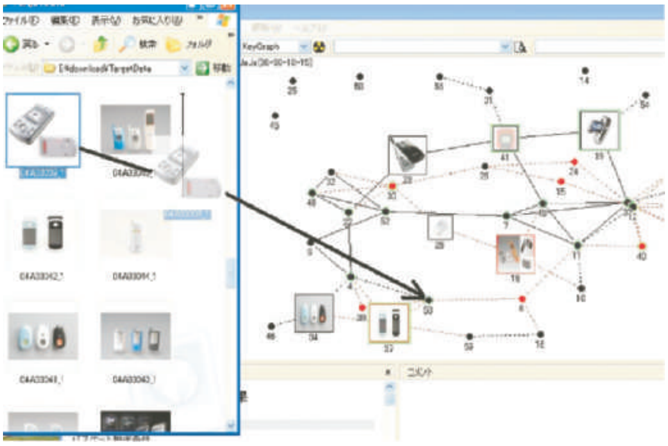

Fig. 2. The usage of Pictorial KeyGraph (on our original software named Polaris [9]) Pictorial KeyGraph.

4 Application of Pictorial KeyGraph to Requirement Reports

4.1 Preliminary study and tasks

We executed preliminary study based on customers' call reports and test reports. The reports were written in free text format by technical sales people, on new functions and new products desired by users, related to linear CCD surface inspection system. The aim of these reports was to well detect defects (scratches on the CCD surface as in Fig. 3), as required by customers, 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, according to our interview to developers of the CCD surface inspector, after processing all reports by KeyGraph working on the Polaris platform [9].

After this preliminary study, we found three major problems which should be settled. First, 20 groups of defects, that include 64 defect categories having some specific nick-names given by the customers, who are experts of CCD production. The meaning of those names were not understood among technical sales people, nor by the managing executive of the technical sales section of the inspector manufacturer. Second, the large majority of these names came to be located as red nodes in KeyGraph, i.e., as bridges. That is, each name rarely in the requirement reports, so that they are hard to understand. Lastly, the meaning of the defect names were ambiguous: Same names were assigned for seemingly different defects, in the customer call reports and test reports.

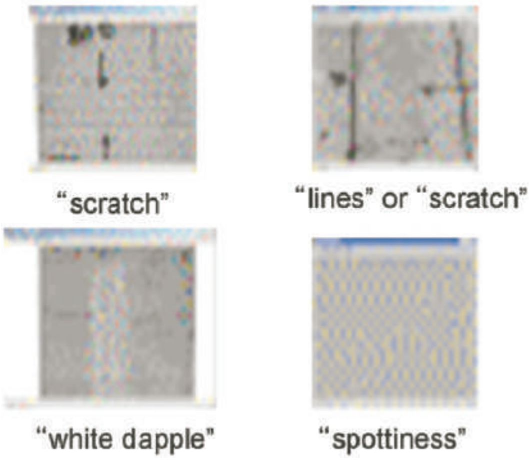

Fig. 3. Defects on the surface of CCD.

4.2 Application of Pictorial KeyGraph to redesigning CCD surface inspector

We executed the following procedure, for 16 sets of reports, each set corresponding to the technical sales staff who presented it.

1. Prepare photographs of all 64 kinds of defects, which can be further classified into 20 similarity groups. Then identify the names used for these defects among the subject customers. These identifications are done by the technical sales staffs of the inspector manufacturer who are usually communicating with the customers (users who are also technicians).
2. Create a graph, with Pictorial KeyGraph, embedding the above photographs of defects to nodes for corresponding names (mainly red nodes on KeyGraph). This embedding task was also done by the technical sales staffs See Fig. 4.

On the way of this procedure, the common opinions of subjects agreed that this enabled to identify the names of defects, and to understand that the defects were related to words in the reports as the bridges among islands. They also understood that the islands corresponded to topics on camera, image processing software, lighting, etc. These understanding were shared by subjects including designers, developers, and the management members of the development section, who had been suffering from miscommunications (see next section).

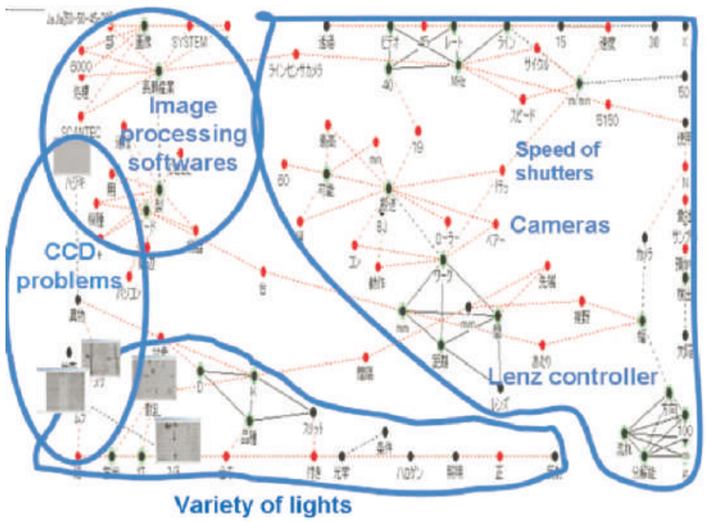

Fig. 4. A result of Pictorial KeyGraph for the reports, on the requirements of customers (the end users of CCD surface defect inspector).

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 out goal to obtain novel business scenarios.

To these subjects, the 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.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 inspector.

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 all characters, all 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 in 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.

The analysis of temporal variance among the number of characters in each scenario and of words for the black or red (hub) 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, according to the curves in Fig. 5.

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

Table 1. 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

3. The number of words for red nodes per scenario increased, just on/after the utterance about a future proposal.

Based on these observations, we hypothesized that the group members first establish their understanding about their frequent experience, and new scenarios emerge from the combination of established islands, and then the awareness of bridging red nodes externalizes the emerging idea into explanatory words (See Fig. 6).

If this hypothesis stands, it gives a useful implication: For example, we can improve the way of use of Pictorial KeyGraph as follows: First show the

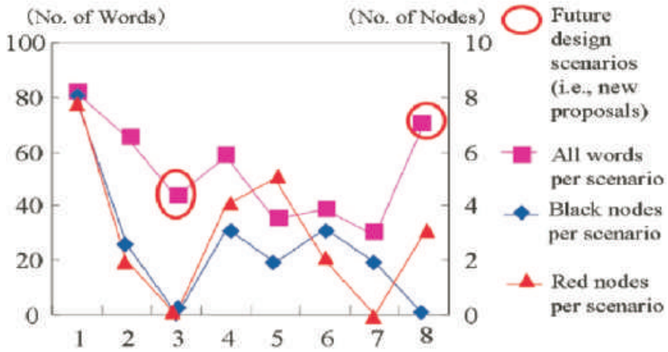

Fig. 5. The temporal variance of the numbers of words and red/black nodes, and the timing of the appearance of future-design scenarios.

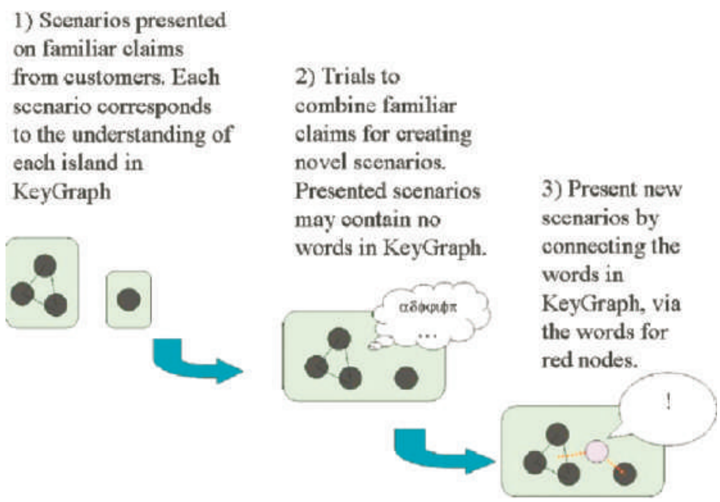

Fig. 6. A hypothetical model of scenario emergence: The participants pay attention to the islands as the building blocks, and the emerging scenario converge into a well-organized description where the blocks are combined to.

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 presented scenarios into 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. 16 of the present-design scenarios contained red (hub) nodes, and appeared one scenario before a future-design.
2. 3 of the present-design scenarios did not contain red nodes, and appeared one scenario before a future-design.
3. 10 of the future-design scenarios contained red nodes.

Thus, we may be able to predict 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 presented scenarios, appearing before and after the appearance of future-design scenarios. Here a topic means a theme discussed, corresponding to the component of the product they considered to improve, e.g., "about camera in the CCD surface inspector" "about image processing software," etc. The results were as follows:

1. For 12 (of 19) future scenarios, the topics were the same as of their preceding scenarios.
2. For 2 (of 12: the other 7 future-design scenarios appeared at the last of discussion, so no scenarios after the 7 could be counted) future-design scenarios, the topics were the same as of their following scenarios.

That is, the topic tends to stay invariant until the appearance of a future-design scenario. However, the topic tends to change suddenly with the appearance of a future-design scenario.

These evidences mean the future designs proposed after the cognition of red (bridge) nodes are focused on a changed context due to the discovery of a chance, corresponding to the item or the word for a red node. This supports the hypothesis depicted in Fig. 6, because human loses words when his/her previous vocabulary comes to be useless due to a contextual shift.

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 a marking system and a marking ink to draw marks near by finely detected 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. This product reflected the five patents below we really applied, which correspond to subgoals 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.

6 Conclusions

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 behaviors were extracted, and 5 new patents have been applied. The CCD inspector developed and sold from this company is the current most well accepted by 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 [10], and has been applied to realizing creative communication environment [11, 12]. However, this paper still presents a new finding. That is, the visualization of Pictorial KeyGraph should be bottom-up, as shown in Fig. 6 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 in suitable words. This finding presents a supportive evidence to the studies in design communication, where good questions make the trigger to good designs [12]. The uncertain information as words in the red nodes has been said to be helpful to creative design [13], but presents even a stronger hint when given at the better timing, i.e., when the designer is asking for a hint for creating a design.

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Is there a Needle in the Haystack?

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Summary. Re-using knowledge in design firms can lead to greater competitive advantage, higher quality designs and innovative solutions. This chapter presents a framework for exploration and discovery of reusable knowledge from a corporate archive as a form of chance discovery. The concepts of the exploration framework are modeled through a prototype, CoMem^{TM} (Corporate Memory). It formalizes the added value of exploration in the process of knowledge reuse. This is based on two hypotheses: (1) exploration is critical for effective knowledge re-use; (2) CoMem enables structured and organized exploration that results in higher quality designs. Two exploration activities are discussed: (i) *Breadth-Only overview exploration* that assist a user to rapidly localize pockets of re-usable knowledge from large corporate archives and (ii) *Iterative breadth-depth exploration* that enables a user to identify those re-usable components of the Corporate Memory that may yield design issues that were not originally considered. To support the needs for collaborative exploration and discovery, CoMem is integrated into an interactive room (iRoom developed at Stanford). This innovative collaborative environment called CoMem-iRoom addresses current state-of-practice limitations that relate to content, context, visualization and interactivity, constraining the process of collaborative exploration towards knowledge reuse and decision-making. Real project scenarios illustrate CoMem and the innovative CoMem-iRoom chance discovery work place that support computer-mediated communication and collaborative teamwork.

1 Introduction

How can a corporation capitalize on its core competence by turning its knowledge into working knowledge when large digital repositories are available? How do you find the metaphorical needle in a haystack? How do you find a needle in a haystack if you don't even know you're looking for a needle, or if you've never seen a haystack before? How can a computer system support designers in reusing solutions and experiences from previous projects? Those are the kind of questions addressed in this chapter.

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Managing and reusing knowledge in design and construction firms can lead to greater competitive advantage, improved products, and more effective management of constructed facilities. However reuse often fails, since knowledge is not captured, it is captured out of context rendering it not reusable, or there are no formal mechanisms from both the information technology and organizational viewpoints to find, explore, and assess reusable knowledge. We define design knowledge reuse as the reuse of previously designed and built facilities, subsystems, or components, as well as the knowledge and expertise ingrained in these previous projects.

This study builds on the notion of *knowledge in context* [5]. Knowledge in context is design knowledge as it occurs in a designer's personal memory: rich, detailed, and contextual. In order for knowledge to be reusable, the user should be able to see and explore the context in which this knowledge was originally created and interact with this rich content. A repository of such knowledge in context is defined as a corporate memory. Knowledge reuse is a step in the "knowledge life cycle" [4]. Knowledge is created as practitioners who collaborate on projects. It is captured, indexed, and stored in an archive. At a later time, it is retrieved from the archive, explored, understood, and reused. Finally, as knowledge is reused it is refined and becomes more valuable. In this sense, the archive system acts as a knowledge refinery.

The digital age holds great promise to assist in content archival and retrieval. Nevertheless, most digital content management applications today offer few solutions to assist designers to find, explore, and understand content in context. State-of-practice document management solutions are limited to digital archives of formal documents logged by discipline, project phase, date, and originator. A typical corporate archive grows as the firm works on more projects. Consequently, it becomes increasingly challenging for users to search and: (1) have a "birds' eye view" of all the corporate projects with flags to relevant past project information pertinent to specific problems they work on, (2) explore specific items in context, and (3) discover reusable items or topics that were originally not considered.

Two key activities in the process of knowledge reuse are formalized based on extensive ethnographic studies of design professionals at work: *finding* reusable items and *understanding* these items in context, i.e., exploration of the context and the history of potentially reusable items [5]. More specifically, designers are able to *find* relevant designs or experiences to reuse. For each specific design or part of a design they decide to reuse, they are able to retrieve a lot of contextual knowledge. This helps them to *understand* this design and apply it to the situation at hand. When exploring contextual knowledge they explore two contextual vectors: the *project context* and the *evolution history*.

2 Theoretical Points of Departure

The points of departure of this research are rooted in design theory and methodology, knowledge creation and management, human computer interaction, and chance discovery.

Design theory and methodology. This research builds on Donald Schön's concept of the reflective practitioner paradigm of design [14]. Schön argues that every design task is unique, and that the basic problem for designers is to determine how to approach such a single unique task. Schön places this tackling of unique tasks at the center of design practice, a notion he terms *knowing-in-action* ([14] p. 50). To Schön, design, like tightrope walking, is an *action-oriented* activity. However, when knowing-in-action breaks down, the designer consciously transitions to acts of reflection. Schön calls this *reflection-in-action*. Schön argues that, whereas action-oriented knowledge is often tacit and difficult to express or convey, what *can* be captured is *reflection-in-action*. This concept was expanded into a *reflection-in-interaction* framework to formalize the process that occurs during collaborative team meetings [6].
Knowledge creation and management. The acts of reflection-in-action of single practitioners and reflection-in-interaction of project teams are part of the knowledge creation and capture phase of what we call the "knowledge life cycle" [4]. As [3] indicates knowledge is created through dialogue within or among people as they use their past experiences and knowledge in a specific context to create alternative solutions. Similarly it represents an instance of what Nonaka's knowledge creation cycle calls "socialization, and externalization of tacit knowledge" [11]. This study builds on these constructs of the knowledge lifecycle and the "socialization, externalization, combination, and internalization" cycle of knowledge transfer.
Human Computer Interaction. The scenario-based design approach [13] is used as a methodology to study the current state-of-practice, describe how people use technology and analyze how technology can support and improve their activities. The scenario-based design process begins with an analysis of current practice using *problem scenarios*. These are transformed into *activity scenarios*, *information scenarios* and *interaction scenarios*. The final stage is *prototyping* and *evaluation* based on the interaction scenarios. The process as a whole from problem scenarios to prototype development is iterative.
Chance Discovery. The double helix process of chance discovery described by Ohsawa [12] corroborates to the approach presented in this chapter. The double helix model has two helical sub-processes. One is the people process, which forms the cycles of human chance-perception progressing to deeper concerns. The second helix is the process of computer processing and data mining revealing possible areas of exploration and discovery of reusable knowledge. The double helix model emphasizes the importance of deepening the human's concern with a chance, by visualizing the interaction between human and environment, between human and human, and between one and oneself. Here, practitioners and an automated data mining systems collaborate, each processing spiral supporting the creative exploration and discovery of future alternative scenarios for the project through a combination of current solutions and reusable knowledge from the corporate memory that was not considered originally.

3 CoMem as a Practitioner's Exploration and Discovery Environment

Informed exploration can lead to the discovery of reusable knowledge as opposed to simple search and retrieval. The CoMem^{TM} [5] prototype is used to model the formalized concepts of an exploration framework. A brief description of the CoMem^{TM} system is provided in the following as a technology point of departure. A scenario of use in a real testbed environment with an archive of 64 projects illustrates the effectiveness of exploration and discovery of re-usable knowledge by a single practitioner. It demonstrates how CoMem^{TM} exploration framework brings to the foreground design issues that the users may not have considered in their original query for re-usable knowledge and results in a more detailed and informed solution.

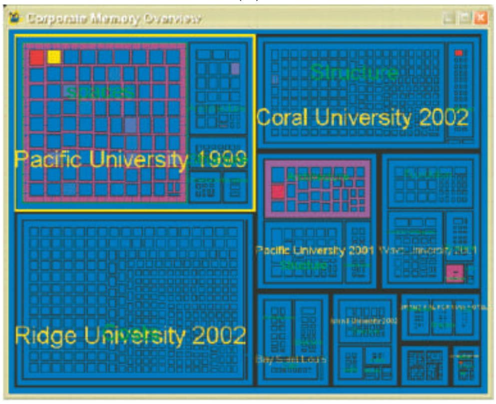
3.1 CoMem^{TM} System Overview

CoMem^{TM} (Corporate Memory) is a collaboration technology that facilitates context-based reuse of corporate knowledge in a single-user setting that has been developed in the PBL lab for the design and construction community [5]. It allows for context based visualization and exploration of large hierarchical project design databases. CoMem^{TM} is distinguished from the document-centric state-of-practice solutions by its approach of "overview first, zoom and filter, and then details-on-demand" [15].

Based on the reuse steps identified during the ethnographic study - *find, explore project context, explore evolution history* - CoMem^{TM} has three corresponding modules: an *overview*, a *project context explorer*, and an *evolution history explorer*. (Figure 1) Each module uses a specific *metaphor* to implement an innovative interaction experience for the user. *Metaphors* are used in a human-computer interaction sense. Metaphors increase the usability of user interfaces by supporting understanding by analogy. Modern operating systems use the desktop metaphor. Online services use shopping cart and checkout metaphors to relate the novel experience of buying online to the familiar experience of buying at a bricks and mortar store. To provide a concrete illustration of the CoMem system a first testbed of 10 building projects was used from the design and construction field. The database archive is organized according to three levels of granularity: projects, disciplines (e.g., architecture, structure, construction HVAC - heating, ventilation, air conditioning, etc.).

CoMem uses a *map metaphor* for the overview. The CoMem Overview Module provides a succinct "at a glance" view of the entire corporate memory. Corporate memories are usually hierarchical, where the corporation contains multiple projects, each project consists of multiple disciplines or building subsystems (structural, electrical, and so on), and each discipline contributes multiple components. This archive can become very large.

(a)



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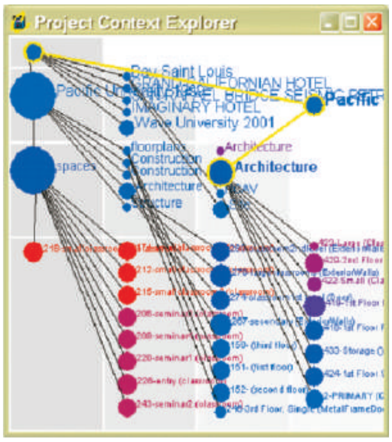

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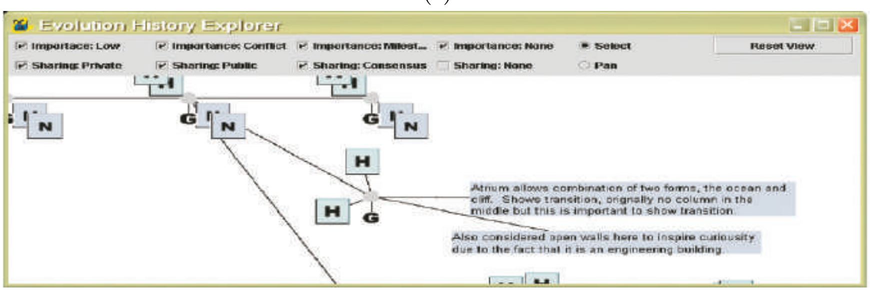


Fig. 1. CoMem^{TM} Modules: (a) The Map Overview provides a succinct snapshot of the entire corporate memory; (b) The Evolution History Explorer allows the user to explore the evolution of an item before reusing it; (c) The Project Context Explorer allows the user to explore related items in the corporate memory to better understand the item.

Conventional techniques for visualizing hierarchies using nodes connected by links are inappropriate, given that the overview needs to show the entire corporate memory in a single display. CoMem uses the "*squarified treemap*" *algorithm* to display an overview of the corporate memory in which the hierarchy is visualized as a series of nested rectangles [15]. The area on the map allocated to each item is based on a measure of how much knowledge this item encapsulates, i.e. how richly annotated it is, how many times it is versioned, how much external data is linked to it. Each item on the map is color-coded by a measure of relevance to the designer's current task. (Figure 1a) Currently, this relevance measure is based on textual analysis of the corporate memory using Latent Semantic Indexing (LSI) algorithm [10].

The CoMem Project Context Explorer (PCE) module enables the designer to explore the project context of any item selected from the overview. This item becomes the *focal point* of the interaction. CoMem uses a *fisheye lens metaphor* for the project context explorer (Furnas 1981) [9]. A fisheye lens balances local detail with global context. This metaphor is used to suggest that the designer is initially concerned only with the item of interest, but begins to explore the context "outwards" as necessary. Given a user-specified focal point, CoMem uses the *fisheye formulation* to assign a degree of interest to every item in the corporate memory (Figure 1b)

Observations show that the most effective means of knowledge transfer from experts to novices is through the informal recounting of experiences from past projects. Stories convey great amounts of knowledge and information in relatively few words. CoMem uses a *storytelling metaphor* for the evolution history explorer. The CoMem Evolution History Explorer (EHE) module enables the designer to explore the evolution history of any item selected from the overview - from an abstract idea to a fully designed and detailed physical component, discipline subsystem, or even entire project. (Figure 1c)

Preliminary pilot projects in the industry indicate that CoMem can be a tool that allows a user to visualize large hierarchies at a glance as well as provides the functionality to explore local context for any part of that large hierarchy. Hence CoMem addresses the content and context based needs in the process of knowledge reuse.

3.2 CoMem Exploration Framework

The proposed exploration framework is based on two hypotheses: (1) exploration is critical for effective knowledge re-use; (2) CoMem enables structured and organized exploration that results in higher quality designs.

CoMem provides a systematic framework for exploration in the process of knowledge re-use that compliments and expands the simple search and retrieval paradigm provided by traditional tools that results in a more detailed and well-informed final design solution. For the purpose of this discussion we will consider that for any two corporate objects A and B, object B is relevant to object A if: (1) the user is currently working on object A and object B is potentially reusable; and (2) the user is considering reusing object A and object B is somehow related to object A, such that knowledge about object B helps the user understand object A or improve the design of object A.

The importance of such an exploration oriented knowledge-reuse strategy can be shown based on the following probabilistic formulation:

The function $Q(A|B)$ is defined as follows:

- The designer is working on the design of item A
- B is an item of information or knowledge from the corporate memory that would be of value during the design of A.
- $Q(A|B)$ is some quantification of the probability of finding the item of information B from the corporate memory or a large archive during the design of A.

For example:
Q(ClarkCenterSteelFrame | FireProtectionManual) is the probability of being able to retrieve a manual on fire protection while a designer is working on a steel frame for the Clark Center project. For a novice designer this probability would be quite small, because a novice might not know that fire protection is a major issue in the design of steel structures, and the terms fire protection might not appear anywhere in the technical documents for the steel frame.

Similarly, Q(ClarkCenterSteelFrame | SteelDesignManual) is the probability of being able to retrieve a manual on steel design while a working on the steel frame for the Clark Center project. Q(SteelDesignManual | FireProtectionManual) is the probability of being able to retrieve a manual on fire protection while reviewing the manual on steel design.Intuitively, the following will be true:
Q(ClarkCenterSteelFrame | FireProtectionManual) << Q(ClarkCenter SteelFrame | SteelDesignManual)
$\times Q$(SteelDesignManual—FireProtectionManual)

In other words, a novice designer working on a steel frame is much more likely to find a manual for steel design and then find a manual on fire protection than he or she would be to find a manual on fire protection *directly* while working on the steel frame.

The framework further formalizes the notion of exploration and classifies exploration activities in the following two categories:

- *Breadth-Only overview exploration* that helps localize pockets of re-usable knowledge from the large corporate archive and
- *Iterative breadth-depth exploration* that helps discover those re-usable components of the Corporate Memory that may not be contextually relevant to the original problem query at hand.

Exploration that combines both types of activities, i.e., breadth-only and breadth-depth, will bring to the foreground design issues that the users may not have considered in their original query for re-usable knowledge and will result in higher quality solution.

The exploration activity in CoMem is initiated through a user text query. Based on the query a color-coded map is computed through the LSI engine and presented to the user (Figure 2). On this map, all items are coded in colors ranging between red and blue in decreasing order of contextual relevance to the original query, red items being the most relevant and blue items being the least relevant. This relevance score is obtained through the latent semantic indexing algorithm applied to the document corpus of the archive.

The first type of the exploration activity that a designer can carry out is the *Breadth-Only Overview Exploration.* Such exploration activity is appropriate when the designer is seeking extensive information and insight on multiple knowledge areas. The designer initiates this activity by submitting to CoMem, queries for each of the knowledge areas that he is interested in exploring and correspondingly obtains differently color coded overview maps for each of these queries. Each map identifies parts of the Corporate Memory that would be of interest to the designer in exploring the aforementioned knowledge areas. Based on these maps the designer can identify projects and disciplines of the Corporate Memory that reference all or most of the different knowledge areas he is interested in exploring and hence carries out localized exploration of those projects or disciplines. Having found such projects and disciplines of

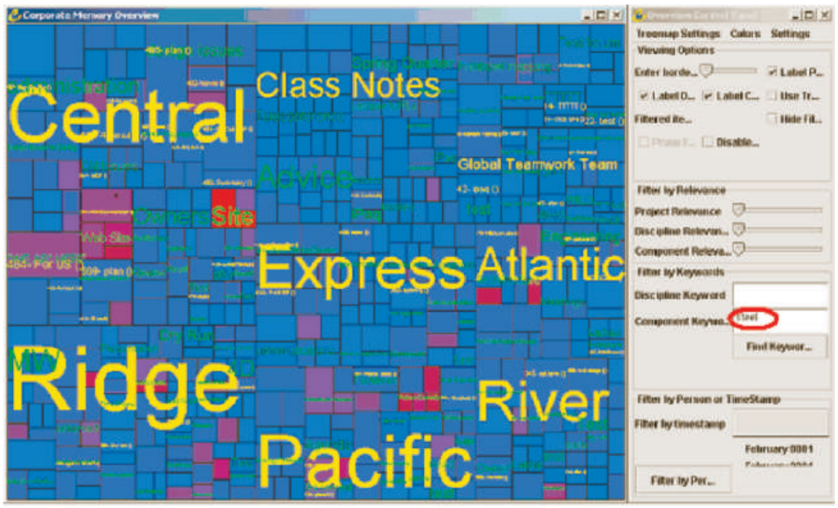


Fig. 2. User types in a query, e.g., "steel" and is presented with a CoMem Overview Map highlighting items of high relevance in the corporate memory.

the Corporate Memory that reference all the queried knowledge areas, the designer can further explore these through the CoMem, e.g., corporation's project archives, or feedback from an expert in the corporation who has worked on these projects and disciplines.

Assume a designer seeks insight in knowledge areas X, Y and Z. He creates queries for each of these areas that result in three maps correspondingly as shown in Fig. 3. The designer finds projects A, C and D relevant to knowledge area X, projects A,B and C relevant to knowledge area Y, and projects B,C and E relevant to knowledge area Z. The designer localizes his exploration to project C as it references all the three knowledge areas he is interested in and goes through all the information available through the corporate memory. The designer further speaks to his/her senior at the firm who has worked on project C and obtains the necessary insight (Figure 3).

The second type of exploration activity that a designer can carry out is an *iterative breadth-depth exploration.* Such exploration is appropriate in a situation where a designer has a target end component design but is not aware of all design aspects that need to be considered for this component. The designer first formulates the query based on all knowledge areas associated with

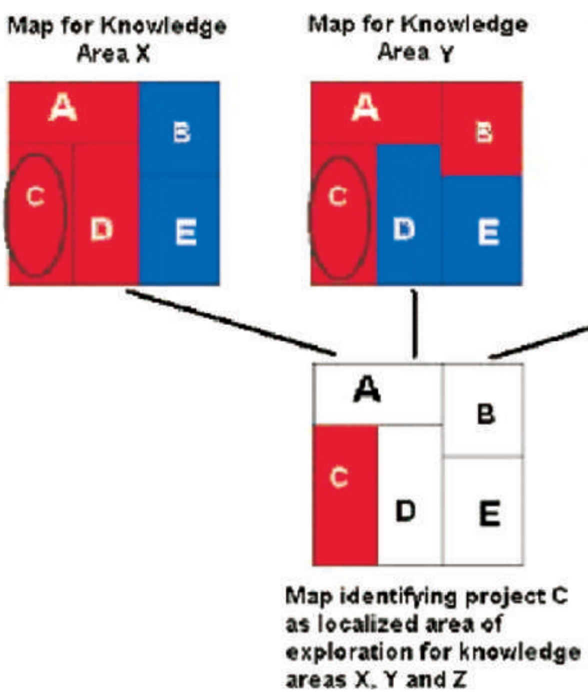


Fig. 3. Maps corresponding to queries for knowledge areas X, Y and Z. Map showing localized area of search as project C for all knowledge areas of interest X, Y and Z.

the design that he is aware of. Based on the query CoMem will present to the designer a color-coded map that identifies all items in the corporate memory that are relevant to the knowledge areas represented through the query. The designer then explores the context of the most relevant items in the map through the project context explorer (PCE). As mentioned earlier, the item of interest selected from the map becomes the focal node in the project context explorer, with all relevant items organized in decreasing order of structural distance (defined as 1 if item is in same project and discipline as focal item, 2 if the item is in the same project but a different discipline and 3 if both items are in different project and disciplines) and contextual relevance. This organization of the project context explorer provides the designer with the opportunity to carry out a detailed exploration of the context of each relevant item. The designer can browse through the different versions associated with any item of interest within the EHE that displays all the versions on an item being invoked from the PCE. This constitutes the depth-based exploration in this process. Based on information acquired in this manner the designer can decide to further explore the context of an item that he/she finds interesting. Invocation of any item within the PCE presents to the designer a new PCE with the invoked item as the focal node and its corresponding context. This constitutes the breadth-based exploration in this process.

Such interwoven breadth-depth exploration allows the designer to unearth knowledge areas and design aspects associated with the target design that was unaware of originally. The user is made aware of such unknown design aspects as a result of contextual exploration of items that represent entry points to contexts tangential to the context being explored by the user. Typically such items have medium to high contextual relevance and a high structural distance from the focal node. Substantive exploration of such tangential contexts through the project context explorer informs the user of different knowledge areas and design aspects that he had not considered in the original query.

3.3 CoMem Testbed

To demonstrate the value of CoMem for exploration in the knowledge reuse process requires a testbed made of a database of appreciable size comprising of previous projects of a corporation. The ThinkTankTM archive is one such database that evolved in real-time over a period of a couple of years (Figure 4). Specifically, ThinkTank is a web-based asynchronous communication and collaboration environment, developed at the PBL Lab at Stanford. It provides many of the advantages of face-to-face team meetings combined with the utility of e-mail and the organization of database technology (Fruchter et al 2003). ThinkTank facilitates project team members to create, capture, share, email, reply, attach additional documents, track, sort, search, archival, and re-use data, information, and knowledge. ThinkTank functionalities evolved based

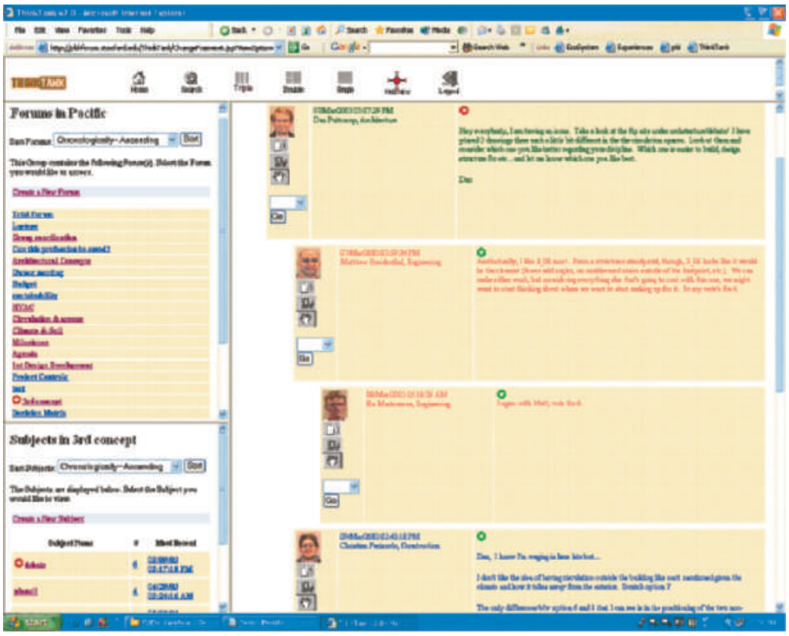
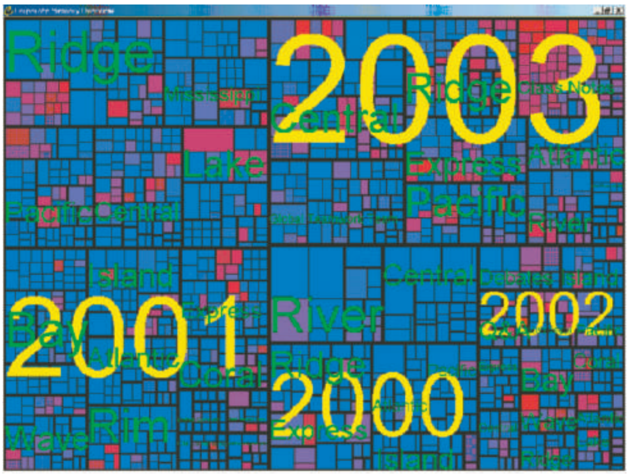


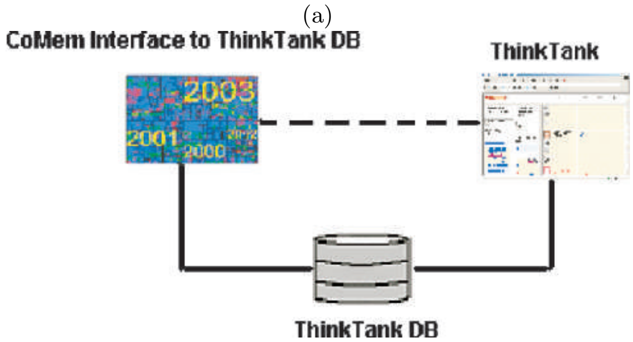
Fig. 4. Screen snapshot ThinkTank™ of the Ridge2005 team discussing issues about the first floor plan of their building. Architect Dan from Kansas University, Structural Engineers Matt from Stanford and Bo from KTH Sweden Construction Managers Christian from Stanford University and Andrea from Bauhaus University Germany.

on ethnographic studies of the state-of-practice in industry and academia focused on the cross-disciplinary project team communication needs.

ThinkTank uses Microsoft Access™ as the underlying database that is organized by project groups, with each project group having a private, password-protected, virtual project space. Within the project space the content is organized based on the "book" metaphor with three levels of organization: *Forums* representing key project disciplines or project phases for instance similar to book chapters, *Subjects* representing or discussing component design issues brought up within a *forum* or a *discipline*, similar to section within a chapter of a book, and threaded *Messages* representing the actual ideas captured and shared among team members, similar to the paragraphs within a section of a book (Figure 4). Messages are created as needed over the course of the project by the team members. Each group can create any number of forums, within each forum there can be any number of subjects, within subjects any number of threads, and within threads any number of messages. Within the context of project communications, there are no practical limits to the numbers of each.



(a)



(b)

Fig. 5. The CoMem as the front-end to ThinkTank database: (a) CoMem Overview Map, (B) CoMem-ThinkTank.

ThinkTank with CoMem were integrated to provide rapid navigation, search, exploration, and knowledge re-use (Figure 5). The resulting CoMem-ThinkTank implemented testbed, consists of an archive that is constantly growing and currently includes 64 projects over a period of a couple of years. These 64 projects comprise of 780 disciplines and approximately 2400 components with 8000 versions in all.

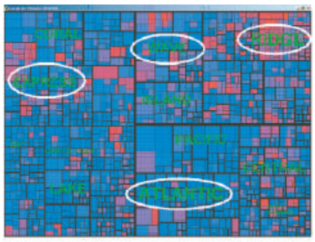
3.4 Single User Exploration and Discovery Scenario

The following illustrates a single user exploration and discovery design experience with the deployed CoMem-ThinkTank system in a real project test case.

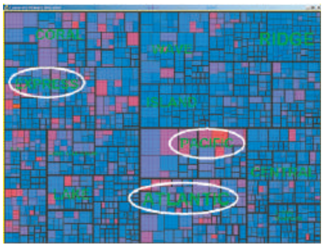
Joe is a novice engineer in a mid size structural design firm. He is working on his first building project - a Hotel in Sacramento. He was assigned to work on a steel structure alternative that would address the architect's concept for the hotel and the overall "sustainable design" objective of the project. The architect's concept has a large atrium in the center of the building and use exposed a MEP system to give the building a mechanical toy look and feel. Joe decides to explore some of the firm's past projects and find reusable concepts and details for steel structure schemas, atrium solutions and exposed MEP approaches. Over the years the firm worked on more that fifty projects and has archived in ThinkTank the concepts, solutions, interactions and communications that led to decisions.

Joe decides to start with a breadth-only search and identify the key projects he could further explore in detail. For this purpose Joe opens CoMem-ThinkTank and performs separate searches for the following topics: LEED for sustainability information since this is his first time he tackles this topic (Figure 6a), steel structure (Figure 6b), atrium (Figure 6c), Exposed MEP (Figure 6d). For each search CoMem returns a color-coded Overview Map of the large corporate archive indicating the potential projects (areas on the map) that are relevant to his specific search. The color-coding scheme uses red for the highest relevance related to the query, blue for the lowest or no relevance to the query, purple spectrum for the contextually relevant and related items. Each map has a number of rectangles color-coded in red, which Joe plans to explore. He was able to quickly run the queries and obtain multiple, contextually color-coded Overview Maps that provide him with complete and succinct overviews of the large corporate archive, he can decide at a glance which projects address multiple issues he is interested in and explore those first. In this case Pacific project - has items highlighted in red in two Overview Maps that represent the steel structure and exposed MEP queries, and Ridge project - has items highlighted in red in three Overview Maps that represent the steel structure, LEED, and exposed MEP queries. Wave project has items highlighted in red in two Overview Maps steel structure and exposed MEP queries, and Atlantic project has items highlighted in red in two Overview Maps steel structure and atrium queries. Joe decides to explore in detail the projects in the following order Ridge, Express, Pacific, and Wave projects based on the identified overlaps in query results shown in the four Overview Maps. He starts a detailed breadth-depth iterative exploration by using the PCE and EHE of CoMem.

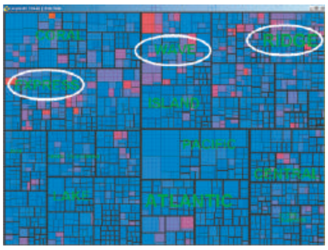
At some point during his exploration, Joe selects steel structure item in the Pacific project in the Overview Map. As a result, the PCE and EHE are updated and the relevant data is retrieved from the database. (Figure 7) As he explores the PCE that has "steel structure" in the focal point he discovers that another relevant item that is colored in purple is labeled "exposed ceiling" and is part of the "fire protection" subject. This is a sideway exploration on a subject that is contextually related to "steel structure." Since Joe is a novice engineer, he did not know that for steel structures he has to consider fire protection. He decides to learn more about it and explores the threaded discussion items related to "fire protection" and "exposed ceiling" in the EHE.



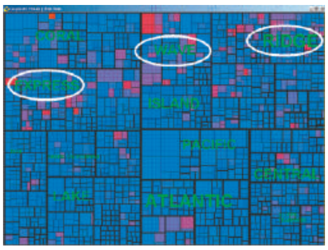
(a) Query: LEED



(b) Query: Steel Structure



(c) Query: Atrium



(d) Query: Exposed MEP

Fig. 6. Areas of Interest for Exploration in CoMem Color Coded Maps for Different Search Queries.

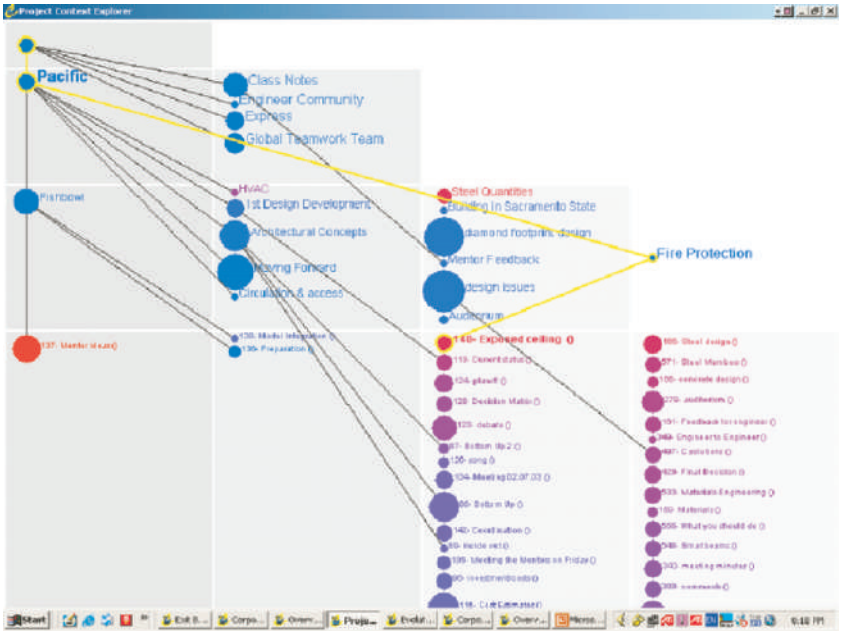


Fig. 7. CoMem Project Context Explorer (PCE) with "Steel Structure" item of Pacific Team in the Focal Point. Exploration of Relevant items (purple colored) in the PCE Joe Discovers "Exposed Ceiling" and "Fire Protection" as items related to steel structures that he did not consider before he started his exploration for reusable knowledge.

He decides to reshuffle the configuration of the PCE with "exposed ceiling" and with "fire protection" in the focal point. This helps him visualize, explore and discover other topics related to steel structure and exposed ceiling that he was not aware. During this iterative breadth-depth exploration he discovers some interesting structural connection details and valuable pointers to MEP subcontractors that he might contact in case the project team decides to opt for the steel structure solution.

New items become closer to the focal point as their relevance increases with respect to the new point of interest. Consequently, even though Joe did not think of fire protection issues related to steel structures, and the relation between exposed MEP and ceiling, CoMem affords the search and discovery of these key design aspects.

4 Collaborative exploration and discovery of reusable design knowledge

Members of design and construction teams often attempt to share and reuse their knowledge gained in previous projects. This collaborative knowledge reuse from past experiences involves exploration of design content stored in corporate project design repositories and archives either in digital or paper format. However, these archives do not capture the entire design process thereby resulting in loss of contextual information. These archives tend to store large amounts of unorganized but nevertheless, very rich content (blueprints, pictures, calculations etc.). The process of collaboration in such a setting entails participants looking at large amounts of decontextualized design data over limited physical and visual space with team-members often making inaccurate assumptions about design process decisions and justifications, and most importantly missing many knowledge reuse opportunities since they can not find relevant items or the connection between them.

Issues that limit the process of collaborative exploration of these project archives and repositories are broadly classified into three categories: *content* based limitations, *context* based limitations and *visualization* limitations. To address these issues CoMem is integrated with the iRoom framework. The iRoom architecture was developed through the Interactive Workspaces project by the Human Computer Interaction (HCI) group at Stanford University [1, 2]. It investigates human interaction in ubiquitous computing environments comprised of large displays. The hypothesis is that the integration of these two technologies, i.e., CoMem and iRoom, results in a workspace that is ideally suited to the process of collaborative exploration and addresses the need for all participants to explore and manipulate rich content concurrently and effectively in support of knowledge discovery and reuse. This expands the single user CoMem framework for exploration and discovery of reusable knowledge to a collaborative integrated workspace, CoMem-iRoom. The collaborative exploration process supported by this integrated workspace is discussed in the next sections and the benefits of the proposed system are demonstrated through an observed scenario in a real project team.

4.1 Teamwork State-of-Practice

Consider the following scenario that highlights the deficiencies of the state-of-practice in the collaboration process of exploration and knowledge re-use in design and construction teams. In the scenario that is based on a real case, an inter-disciplinary team meets in a conference room to discuss preliminary design aspects of a university building.

Dan, Bo, and Andrea are the architect, engineer, and construction manager, respectively, in “X Inc.” firm working on the design for a proposed 60,000 sq. ft. building for the Engineering department of Pacific University, on the California coastline. The timeframe for this design-build project is short - approximately 12 months - so they work together regularly to speed up the design process. They agreed to meet to discuss aspects of the building design and construction. During their conversation, they discuss the current issues related to the proposed HVAC (heating ventilation and air conditioning) standard embedded ductwork system. Are there other options? Bo proposes to explore other ductwork for the building's atrium, rather than having them cut into the structure and plenum space in the hallways. Dan immediately rejects the idea, explaining that any other ductwork would ruin the architectural concept of the atrium. Andrea interrupts and begins to sketch out how a different ductwork will be constructed, and how it would complement the architectural concept. Dan has a difficult time understanding Andrea's sketches, so Bo leaves to retrieve material from past projects. He has difficulty searching through the company's extensive digital and paper file repositories, specifically, trying to determine which files relate directly to the ductwork system in previous projects. After twenty minutes of frustrating search, he returns with a roll of MEP (mechanical, electrical, plumbing) blueprints. Dan and Andrea search through the blueprints and find a few pages with details that document the HVAC. Due to the schematic nature of the drawings, Dan has difficulty visualizing the entire system, and how it relates to other aspects of the building. In searching through the documents, they've spread on the conference table, and have difficulty referring back to the material that they'd already found. Dan becomes frustrated trying to correlate data among layers of blueprints and other related documents, and is still concerned that the differences in the architectural concepts are too big to make a comparison between them. He explains that he has a hard time linking all the pieces together to understand how they evolved, and he wants to know how other aspects of the building design were affected by the choice of exposed HVAC. Dan remains unconvinced and argues that this specific past project example does not translate to the context of the current project, and dismisses this option. He leaves wondering if "X Inc." has other past project solutions that would be more appropriate to their current ductwork problem.

This scenario reveals a number of critical limitations constraining the described process of collaborative exploration and decision-making through knowledge reuse:

- **Content Based Limitations** - Current archives tend to be large, incomplete and disjoint making retrieval and exploration difficult and time-consuming. This is clearly visible in the above scenario where Bo has difficulty exploring the company's entire project archive and thereby ends up retrieving decontextualized information from a past project with the key steps in the design decision process missing.
- **Contextual Limitations** - Archives of past designs do not retain sufficient context within which design decisions were reached. Little information about the design process or intermediate design versions is retained thereby leading to decontextualized design data.

- **Visualization and Interactivity Limitations** - Limitations on direct manipulation and visualization of rich content as most of these designs occupy large display spaces (digital or physical) and allow for limited manipulation resulting in a constrained interaction process. Such a constrained interaction process poses difficulty to compare retrieved documents and identify the relevance of those retrieved documents to the problem at hand. It also leads to constrained knowledge exploration as participants manipulate and explore partial information as many documents from intermediate phases are not archived and the parts of the retrieved documentation are not linked.

4.2 CoMem-iRoom Approach

The integrated CoMem^{TM}-iRoom architecture presents an innovative environment that addresses the identified limitations in the process of collaborative teamwork for knowledge exploration and reuse. The interactive Room (iRoom) architecture [1] is a technology that enables communication between discipline-specific control applications running on multiple machines. By making CoMem^{TM} the nodal application of the iRoom architecture, we extend the single-user contextual visualization and exploration functionality provided by CoMem^{TM} to a multi-user interactive setting, thereby enabling collaborative exploration in project group meetings and knowledge reuse discussions.

iRoom Architecture

The iRoom architecture has been developed by the HCI group at Stanford University as a part of the Interactive Workspaces project started in 1999 in the Human Computer Interaction (HCI) Group in the Computer Science department at Stanford University [1]. The objective of the project has been to investigate human interaction with large resolution displays embedded in ubiquitous computing environments that could sustain realistic interactive use. Specifically, the objectives of the collaborative work space are:

- Ability to map a single defined physical location to an underlying systems infrastructure.
- Emphasis on the use of large interactive walk-up displays with touch interaction.
- Integration of ‘nodal’ domain applications in the iRoom architecture.
- Control processes running on different PCs that ensure seamless and smooth interaction.

The original prototype of the iRoom included a number of touch-sensitive white-board displays along sidewalls. This environment was made available to the other research groups at Stanford University that collaborate with the HCI group such as the PBL Lab.

The iRoom facilitates tasks with the following three characteristics:

- **Moving Data**: Multiple users in the room can move data among the various visualization applications running on different devices such as PCs with large screens or laptops or PDAs.
- **Moving Control**: To minimize disruption during collaboration sessions, any user is able to control any device from his or her current location.
- **Dynamic Application Co-ordination**: Embedded nodal applications that need to communicate with modules on other screens (machines) have communication modules that integrate with the iRoom communication functionality.

The software infrastructure supporting the iRoom architecture is called iROS (Interactive Room Operating System). It is a meta-OS that ties together devices each having their own low-level OS. iROS has three subsystems: *Data Heap*, *iCrafter* and *Event Heap* addressing the three user modalities of moving data, moving control and dynamic application co-ordination. CoMem was integrated with the iROS and the Event Heap subsystem. The Event Heap [2] is a co-ordination infrastructure for iROS derived from a tuple space model which offers inherent decoupling. It stores and forwards messages known as events, each of which is a collection of name-type-values fields. Examples of such fields in a message could be *application_name*, *addressed_from*, *addressed_to* etc. It provides a central repository to which all applications in an interactive workspace can post events. An application can then selectively choose to pick up events from the event heap that are addressed to it and decide on actions to perform locally. In general, iROS applications do not communicate directly with one another but instead communicate through the Event Heap as it helps avoid highly interdependent application components that could cause each other to clash. The Event Heap further allows decoupling of applications referentially with information being routed by attributes rather than by application name i.e. applications are referred to by attribute values and not names thereby allowing grouping and ungrouping of applications sending messages. The CoMem-iRoom configuration includes the following fixed devices: (1) three PC Clients connected to large displays that can be Smartboards for direct manipulation and or projection screens, (2) an Event Heap PC, and (3) a CoMem database PC.

CoMem-iRoom System Architecture:

CoMem$^{\mathrm{TM}}$ embedded as a nodal application to iROS addresses the visualization and interactivity limitations constraining the collaborative knowledge reuse process. *The CoMem^{TM} -Villager* metaphor is introduced to help visualize the system architecture. The rationale being that individual CoMem$^{\mathrm{TM}}$-Villagers communicate just as villagers co-existing in a village exchanging information. Each CoMem$^{\mathrm{TM}}$-Villager resides on a networked host that is a part of the iRoom architecture. The integrated CoMem$^{\mathrm{TM}}$-iRoom environment is then a collection of CoMem$^{\mathrm{TM}}$-Villagers communicating with each other in the networked CoMem-iRoom architecture (Figure 8). Specifically, the integrated CoMem^{TM}-iRoom has the following system components:

CoMem^{TM} - Standalone

This is the standalone single-user CoMem^{TM} version that has been developed by the PBL Lab [5]. It was augmented with a control interface that allows users to determine specific actions and CoMem^{TM}-Villagers on which they intend to execute those actions.

Action & Target Selection interface:

The CoMem^{TM}-Villager has an *Action and Target Selection* graphical user interface (GUI) that contains a set of menus that allow a user to select a given action and the CoMem^{TM}-Villager on which to execute those actions. The list of actions available is dynamic and varies depending on which CoMem^{TM} module this interface is invoked from as the set of accessible components in each module vary. For instance, the list of actions if invoked from the Overview Map would give the user a choice to open a new Project Context Explorer or a new Evolution History Explorer, where as the list of actions if invoked from the Evolution History Explorer, would give the user a choice to open a graphic, hyperlink, note, notification etc.

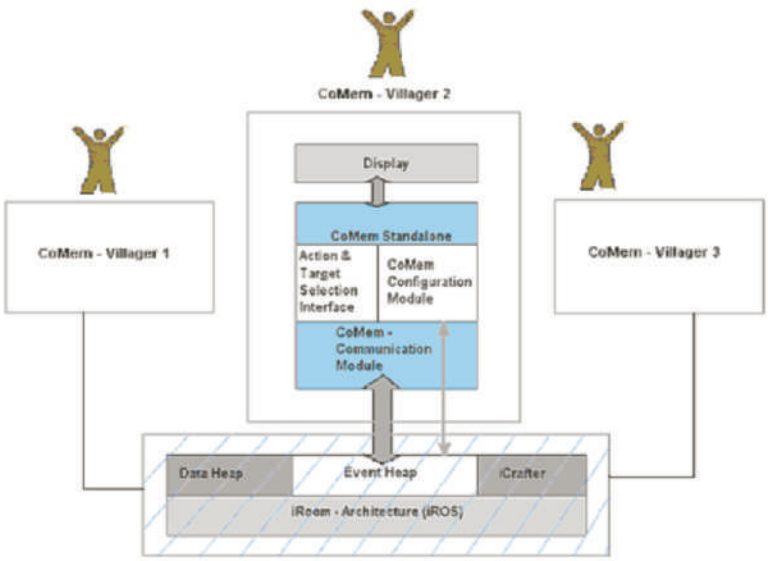


Fig. 8. CoMem-iRoom System Architecture: CoMem^{TM} -Villagers integrated with an iROS (iRoom Operating System) exchanging information through the Event Heap.

CoMem^{TM} - Communication Module:
The communication module was developed as a functional extension to the CoMem^{TM}-Standalone module as described above. This module acts as an interface between the Event Heap in iROS and CoMem^{TM}-Standalone module. The CoMem^{TM}-communication module coupled with CoMem^{TM}-Standalone and the Action-Target selection interface forms a CoMem^{TM}-Villager implementation.

System Configurations Module:
Each CoMem^{TM}-Villager uses a configurations module that allows the user to configure the local preferences and network communications on a specific CoMem^{TM}-Villager. Specifically, the module allows for:

- Modification of user-preferences for the usage of CoMem^{TM} -Villager.
- Maintenance of *public* / *private status* of the CoMem^{TM}-Villager corresponding to send & receive actions. Specifically, a CoMem^{TM}-Villager in *private status* will ignore all actions and components directed towards it from other villagers and allow only one-way outgoing communication. This is necessary if a user on a *private* CoMem^{TM} -Villager wants to explore a given CoMem^{TM} module at length while letting other participants continue to collaborate.
- The configurations module is also responsible for maintaining a registry of other CoMem^{TM}-Villagers currently registered with the Event Heatp and logged into the iRoom.
- **iROS - Event Heap**
  The Event Heap of the iROS architecture used in the development of the integrated CoMem^{TM}-iRoom architecture. The Event Heap allows for decoupling of communication between applications. This is achieved through a common communication format (tuples of the form name-type-value) and access to all the CoMem^{TM}-Villagers.

Communication Process

The following interaction sequence during the communication process between two CoMem^{TM}-Villagers, say CV1 and CV2 being used by Users A and B respectively who are trying to reuse knowledge related to a item X in the CoMem archive.

- User A finds component X to be of interest on the CoMem Overview Map. He further explores it and decides to send the Project Context Explorer of the item X to User B using CV2. To perform this action
  - User A selects the item X on the CoMem Overview Map on CV1. A menu displays possible actions of invocation from the Overview map,

  and destinations for display on CoMem-iRoom clients. This is controlled by the Action-Target Selection interface. It in turn retrieves information about other villagers from the System Configurations Module.
  - User A decides to send "Execute Project Context Explorer with item X on CV2" as the action to be executed on target villager. This command is decomposed into two components: (1) an action that performs the task "Execute Project Context Explorer with component X" and (2) Destination Villager-"CV2". These two components are packaged into an Event Heap readable tuple format by CV1's communication module, and sent to the Event Heap.
- The communication module which is continuously polling the Event Heap for messages directed towards itself notices a new tuple with destination "CV2". The communication module picks up the tuple and reconstructs the packaged Action: "Execute Project Context Explorer with item X".
- This reconstructed action is sent to CoMem^{TM}-Standalone module of CV2, which is connected to the CoMem database, and executed.
- The Project Context Explorer with component item X is displayed on CV2.

4.3 CoMem^{TM}-iRoom in Action

The following CoMem^{TM}-iRoom scenario describes the interactions among an architect, an engineer and a construction manager from a real-world project test case. The following CoMem^{TM}-iRoom workspace was deployed for this project case study: one PC connected to an interactive SmartBoard, two PCs connected to regular projection screens, one shared Tablet PC (instead of an interactive table envisioned in Figures 13), and a laptop. The CoMem-iRoom images shown in Figures 13 correspond to actual screen snapshot taken from these computers during the observed team meeting. The CoMem database testbed consisted of the 64 projects archive created over a couple of years.

- Dan the architect, Bo the engineer, and Andrea the construction manager meet in the corporate decision room to discuss the HVAC issue. Andrea opens a CoMem-iRoom Villager (Figure 9) and enters a "ductwork system" search in the CoMem Overview Map on the center screen (B). She finds several projects in the Corporate Map that are shaded red, indicating high relevance. One of them is Coastal University project. She finds the HVAC system she'd like to explore, and selects it. A menu appears that displays the choice of opening an Evolution History Explorer (EHE), Project Context Explorer (PCE), or Unversioned Modeling Component (UMC). Andrea has the option of opening any of these modules on any of the Villagers in the CoMem-iRoom. She decides to open the Map component's EHE on the Villager running on the left display (A), and its Project Context Explorer on the Villager controlling the right display (C).

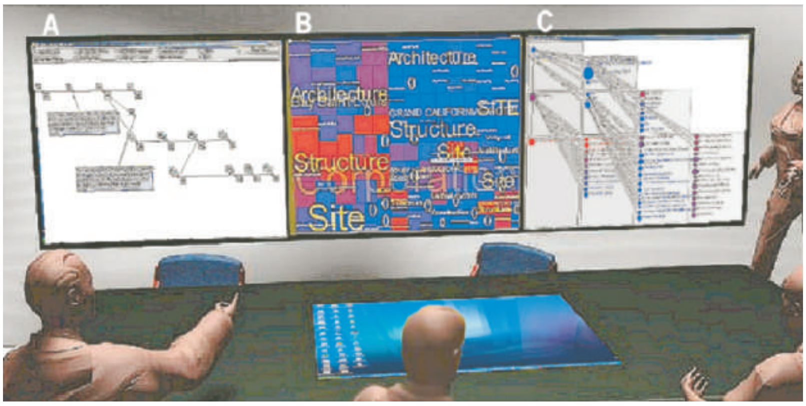


Fig. 9. Andrea opens CoMem Villagers on all three hosts in the iRoom and searches for the Coastal HVAC design. CoMem EHE (A), Overview Map (B), and PCE (C) are displayed.

- The EHE displays that the HVAC component evolved in three primary stages during its design, and documents the points at which critical decisions were made to switch from one version to another. The documents include notes, drawings, images, and URL's from various stages in the design process. The Coastal University project reveals an exposed ductwork solution. Dan has several questions: What was the impetus for switching from a plenum to exposed ductwork system? What impact did this have on the architectural design? How did the designers account for the other implications of this decision? Were any other potential solutions explored? Dan decides to explore two of the versions - one before a critical decision, and one after the decision. On the EHE, he opens notes associated with them (Figure 10, A), and then opens an image associated with the first version on the center screen (B), and an image associated with the second version on the right screen (C). From these notes and images, the group determines that the HVAC system design was altered to include exposed ductwork due to height limitations in the Coastal University project's program. Bo is interested in determining how the installation of the ductwork was designed and how it evolved. Using the Villager controlling the left display, he opens a sketch link on the EHE representing an early version on the center screen (Figure 11, B) and a detail from the final version on the right screen (C). To determine how the architectural concept and other aspects of the building design were impacted by this change, Dan refers back to the PCE of the original HVAC component. The structure and color-coding of the PCE display indicates that there are two other components that have a high relevance to the current HVAC design - the interior atrium of the Coastal University project, and an exposed ductwork system. Dan decides to explore both of them. He opens a CoMem Unversioned

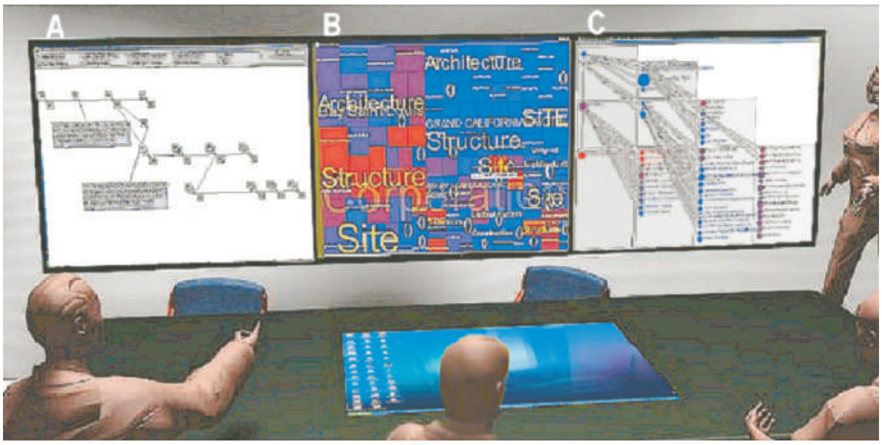


Fig. 10. Dan uses the Evolution History Explorer (A) to explore two different CAD versions of the HVAC component's design development (B, C).

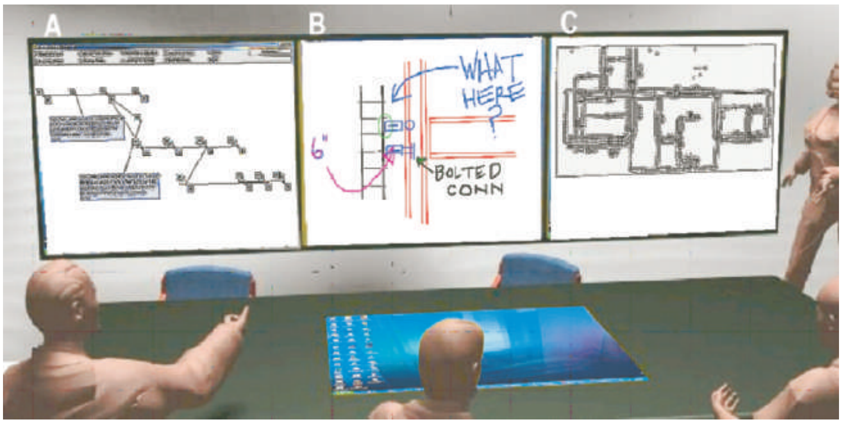


Fig. 11. Bo opens images from the EHE (A) to compare a sketch of the initial exposed ductwork installation design (B) and a detail of the final installation (C).

Modeling Component (UMC) for the atrium on the left screen. The UMC displays all components - images, drawings, notes, and URL's - associated with the atrium, regardless of version. He also opens a UMC for the project on the center screen.

- The atrium UMC displays an architectural rendering of the atrium with the exposed ductwork. It also contains a link to a message in ThinkTank that the team used. Dan opens the link to the message from the EHE HVAC design evolution history (Figure 12, B). Here, the Coastal Univ. project team members describe the many implications and design options

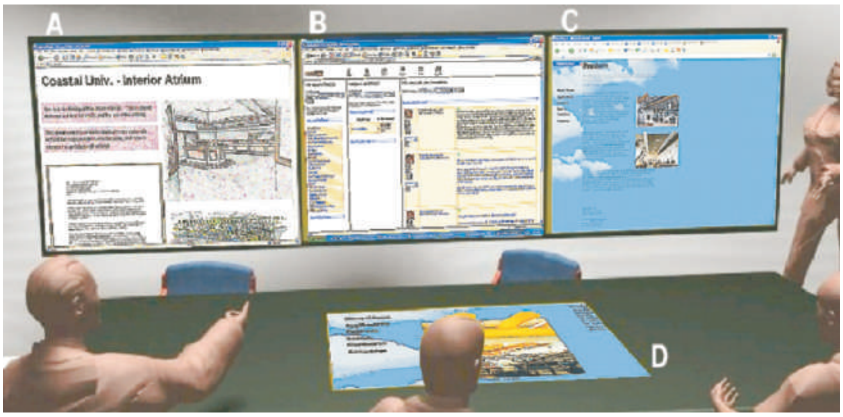


Fig. 12. Dan opens a discussion topic from the Coastal University design team (B). Bo follows a link to the ductwork vendor website (C), and opens a detail of the vendor's smooth ductwork product (D).

for the exposed ductwork system, such as noise considerations and the architect's concerns over the detailing of the ductwork's exterior. Dan discovers that the architect chose the exposed ductwork as an expression of functional transparency, which was a theme of his design. The architect also decided to use the ductwork's ribs to echo the crenellated walls of the atrium's interior. As the current project is an engineering building, Dan had also chosen to use functional transparency as a primary theme. He doesn't like the ribs on the ductwork, however, and wants to know if there are other options. Bo finds a link on the UMC to the ductwork vendor, and opens it on the right screen (C). He locates a system that is available with a smooth surface, and opens a detail of the system on the screen in the center of the interactive table (D).

- While Bo and Dan explore the ductwork system, Andrea opens a new Overview Map on her laptop, which is registered as a CoMem-Villager. She searches for "floor height limitations" (Figure 13, D). In comparing it with the Map on which the original HVAC search was conducted (B), she finds that there are several projects in addition to the Coastal University and California Hotel projects in which floor height limitations appear to have been an issue. She opens a copy of the new Map on the left screen (A) and a UMC for a component with high relevance in the Bay St. Louis project on the right screen (C). This component details an under-floor HVAC system. They explore that option evolution using the EHE, PCE, and details in the CoMem-iRoom. Andrea proposes that the group explore it as another potential solution and compare it with the exposed ductwork option. Dan and Bo agree, having been able to retrieve rich content, and explore and assess the options from the evolution of different alternatives.

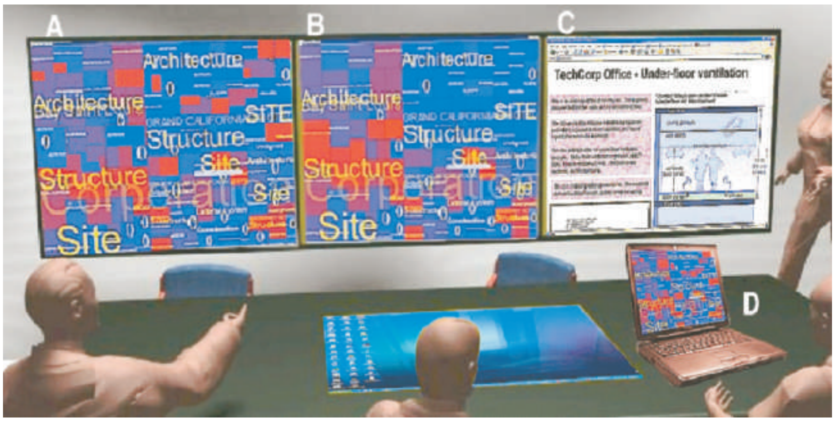


Fig. 13. Andrea opens a new Overview Map and searches for height limitations on her laptop (D). She finds the results interesting, so she send the Map on a large display (A) and a UMC for an under-floor ventilation solution in the TechCorp Office project ib display (C).

CoMem$^{\mathrm{TM}}$-iRoom offers an effective workspace to aid collaborative teamwork in support of exploration and discovery of reusable knowledge. It addresses the identified limitations constraining the current process of knowledge reuse, i.e.: large amounts of content, decontextualization of that content through limited information and knowledge retrieval and difficulties in visualization of such rich content. A CoMem-iRoom pilot was deployed at Intel's Arizona headquarter. The feedback from this preliminary pilot was positive indicating the value of its affordances:

"CoMem^{TM}-iRoom provides great benefits ... Very powerful in its presentation of complete knowledge within context!" - Chris Michaelis - Project Manager, Intel.

5 Discussion

Reusing design knowledge from a corporate archive of past projects is an important process that often fails. This failure can be in part attributed to the fact that state-of-practice archiving systems, e.g., archives of paper drawings or electronic files arranged in folders, do not support the designer in *finding* reusable items and *understanding* these items in context in order to be able to reuse them. Informed *finding*, *understanding*, and *reusing knowledge* go beyond simple search and retrieval and require a capability to support exploration that assists a user as well as a team to (1) gain a global overview of potentially reusable resources form a large corporate memory, i.e., rapid *breadth - only overview exploration* that facilitates localization of pockets of re-usable knowledge from the Corporate Memory; and (2) identify related but critical knowledge, i.e., *iterative breadth-depth exploration* that helps identify those re-usable components of the Corporate Memory that may not necessarily be contextually relevant to the original query at hand. This in turn leads to higher quality designs and reduced rework.

The above examples from real projects emphasize the importance of *contextual exploration* in the knowledge reuse process. In a large repository such as a corporate memory, a valuable item might be beyond the reach of a query such as that supported by traditional retrieval tools. However, by supporting *exploration*, rather than *retrieval*, valuable items can be found in large archives despite the flaws of modern information retrieval systems and the inexperience of a designer. This is especially true for *large* repositories. Figure 14 conveys this premise. For small repositories, traditional tools may be just as effective as or even slightly more effective than CoMem, but their efficacy rapidly declines as the repository size increases.

CoMem^{TM}-iRoom architecture supports:

- Efficient collaborative exploration and discovery of reusable knowledge from an extensive content archive (e.g., testbed archive of 64 projects).
- Communication of contextual information for design components and decisions
- Ability to easily navigate through and visualize multiple pieces of rich content simultaneously by utilizing numerous interlinked and interactive displays
- Visibility of explored content to multiple participants, increasing the opportunities for group learning and chance discovery
- Dynamic adaptability to any number of users and machines used by the group.

These benefits support and demonstrate the research questions, principles of the theoretical points of departure, hypotheses, and objectives of knowledge reuse. They indicate the importance of interactive and iterative knowledge

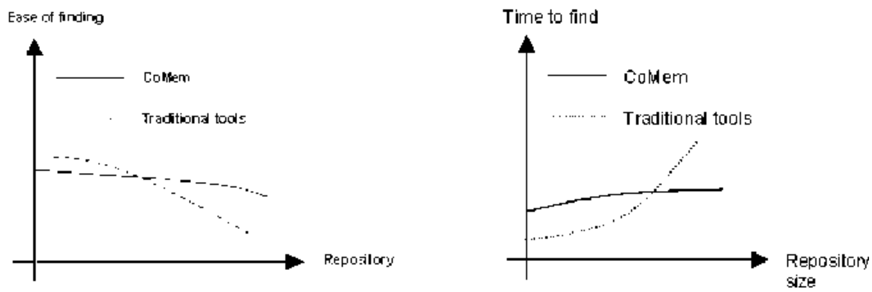


Fig. 14. Performance of traditional tools decreases considerably with an increase in repository size, while the exploration framework provided by CoMem ensures an effective knowledge reuse process.

exploration and discovery process that takes place in a double helix cycle between the CoMem^{TM}-iRoom system and the design and construction team members.

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A Requirement Acquisition Process as an Evolved Chance Discovery

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1 Introduction

Defining what stakeholders really ask for, which is called a scenario acquisition in this paper, is a very important activity for concept making of a new product and system requirements analysis. We will use the term "stakeholders" to refer to all the people concerned with a product and a system, such as end users, suppliers, and manufacturers of the system. The term "scenario" is defined as a serial description of actions of the stakeholders to achieve the requirements and events occurred by these stakeholders' actions.

The scenario elicitation can be replaced by the requirements definition in the requirements engineering domain. The requirements definition process is composed of the following three steps [1].

1. To elicit issues and requirements from stakeholders concerned with a system (requirements elicitation step).
2. To analyze the elicited requirements and to set goals of the system (requirements analysis step).
3. To develop solutions to accomplish the goals and to integrate these solutions into system specifications (requirements specification step).

The requirements engineering has been focusing on the requirements analysis and the requirements specification steps and numerous methods for these phases have been established [2] [3]. However, only a few studies have been made on the method for the requirement elicitation step. Our aim is to establish a systematic method for the early steps of the requirement definition process.

In this paper, we propose a method for the elicitation of requirements and scenarios, with a multi-dimensional hearing and a hierarchical integration process, newly combined on the double-helical model of chance discovery [4].

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Table 1. Basic approach

Issues	Solutions
How to get requirements	Multi-dimensional hearing
How to understand the requirements	Hierarchical integration process
How to integrate the requirements	

2 Target issues and solution

We begin from considering issues on scenario elicitation for a system development. The central work of scenario elicitation is a communication between a requirement analyst and stakeholders.

An interview and requirement meeting are popular as a communication techniques between the analyst and stakeholders [7]. The requirements elicited by the communication are intrinsically incomplete information including lack of information, ambiguity and redundancy. These originate in the following fundamental properties;

1. Stakeholders don't always recognize their requirements: Even if they recognize their requirements, they can only explain these requirements in very abstract words.
2. Analysts often misunderstand these requirements. Because raw demands elicited from the stakeholders are too vague.
3. Analysts often confuse how to integrate the requirements. Because the requirements elicited from stakeholders with various senses of values are rich in diversity.

We aim to establish a new scenario elicitation method to solve the above issues by combining the chance discovery and the requirements engineering methods. Table 1 summarizes the basic approaches of this study.

3 Solutions

3.1 The multi-dimensional hearing method

Although the demands from stakeholders include abundant information, analysts can not utilize these raw demands directly for making scenario [5]. Because raw demands reflect stakeholders' tacit dimension of knowledge such as premises and restrictions in the real usage of the system and the knowledge is not explained explicitly in raw demands.

Approaches to derive such tacit knowledge are important for the communication technique for eliciting a scenario. There are some techniques for deriving tacit knowledge as follows:

- Laddering technique in the marketing research domain [6]
  Laddering is a technique to grasp real demands by repeating "Why" questions.
- Claim analysis in the requirements engineering domain [7]
  Claim Analysis is a technique for clarifying design premises by asking both positive and negative reason for the proposed design.
  Schema of the claim analysis:

  Features of the proposed design is that:
  Positive: xxxxxxx becomes a cause of a desirable result
  Negative: xxxxxxx becomes a cause of an undesirable result

Moreover, from the view of the object driven approach [8] [9] [10], a complete requirement should consist of 3 layers of information: purpose, claim and method of requirement. Each layer of the requirement has premises and restrictions as tacit knowledge individually.

In this study, the claim analysis is reinforced to elicit a useful scenario. Extra dimension of hearings for eliciting knowledge of the purpose, claim and method of requirements, are added to the positive/negative dimension of the original claim analysis method. The hearing method is called hereof the multi-dimensional hearing method and a series of information of about the requirement elicited by the multi-dimensional hearing is called a requirement primitive. A Scheme of the multi-dimensional hearing method is shown in Fig. 1.

The following is the summary list of the multi-dimensional hearing method.

Step 1: When a concrete requirement derives from a stakeholder in interview, positive/negative questions are asked to the requirement (Claim level).

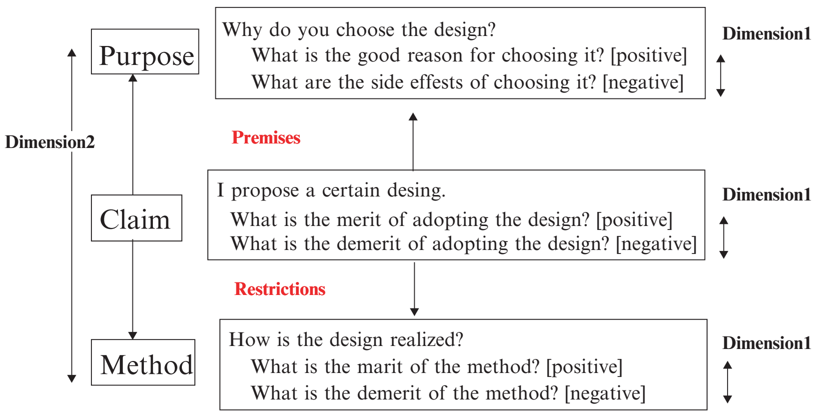

Fig. 1. The multi-dimensional hearing

Step 2: Next, the question "Why do you choose the design" is asked. And positive/negative questions are asked to the answer of the above question (Purpose level).

Step 3: Further, the question "How is the design realized" is asked. And positive/negative questions are asked to the answer (Method level).

3.2 The hiearichical integration process on the double-helical model

In order to construct the requirement scenario unified in a system, the process integrating the requirement primitive obtained from each stakeholder is required. We propose a requirement integration process for eliciting a lot of requirement primitives from each stakeholders and integrating these primitives thorough discussion of stakeholders, on the double-helical model of the chance discovery. The double helical model is a systematic approach to put stress on interaction among stakeholders on a cyclic process.

We design an integration process composed of the inspection test at the front end of the process and the cyclic discussion step on the double-helical model (Fig. 2).

We call the process "hierarchical integration process". Fig. 2 is the summary list of the hierarchical integration process. The inspection test [11] on a proto type is an efficient way to elicit a useful scenario in the early stage of the system development [12].

[Inspection test step]

Step 1: A prototype was shown to stakeholders. A moderator explains its concept and features of the prototype. Each stakeholder writes his/her demands for the prototype on the examination paper.

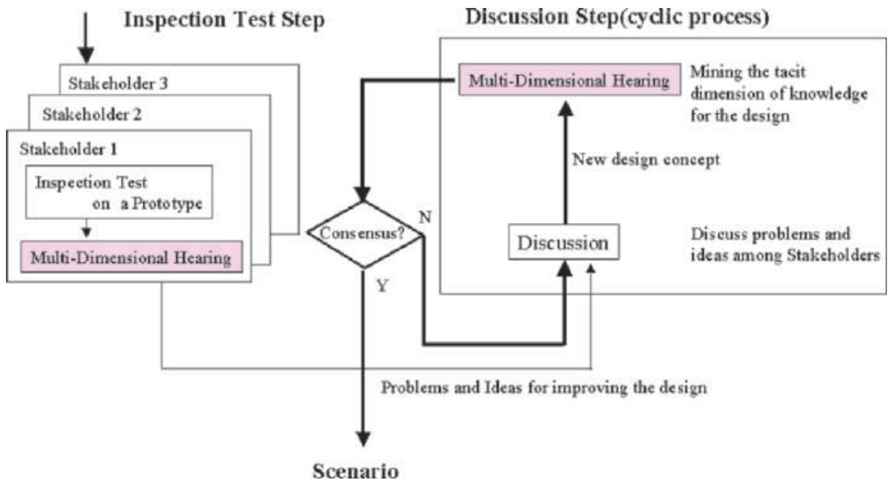

Fig. 2. The hierarchical integration process

Step 2: The Stakeholders explain their demands for the prototype as concrete as possible. The moderator interviews the stakeholders with the multi-dimensional hearing.

[Discussion step]

Step 3: The stakeholders discuss about their demands and propose improvements of the prototype.

Step 4: The moderator interviews the stakeholders about the proposed improvements by the multi-dimensional hearing and return to Step 3 until the consensus of stakeholders about improvements are obtained.

4 Theoretical analysis: How primitives and scenario are derived through the process?

We would like to explain how a requirement primitive and scenario are elicited through the hierarchical integration process by using a visualization tool named KeyGraph [13].

The requirement primitive obtained by the multi-dimension hearing satisfied necessary conditions of requirement utilized for system specifications. The necessary conditions are that each primitive includes information about its purpose, claim-body, method of realization, and their restrictions or premises.

However, the requirement primitives are not enough to use as a system specification directory. Because, inconsistency and subordination between requirement primitives are existing. Unifying the primitives with such inconsistency and subordination into a consistent scenario by mutual consent of stakeholders, is essential for eliciting the requirement scenario.

In this chapter, the acquisition process of a requirement primitive and the requirement scenario are visualized step by step with KeyGraph.

4.1 KeyGraph for visualizing scenario map

KeyGraph is a tool for visualizing the map of word relations in requirements. By visualizing a map where words from data appear connected in a graph, one can see the overview of the world of stakeholders' concern. Suppose data (string-sequence) D is given, describing an event-sequence, with periods (".") inserted at the ends of defined sequence units. For example, let text D be as in Eq. (1)

$$\begin{aligned} D = a1, a2, a4, a5 \ldots . \\ a4, a5, a3, \ldots . \\ a1, a2, a6, \\ a1, a2, a5, \ldots, a10. \\ \ldots . \end{aligned} \tag{1}$$

On data D, KeyGraph runs in the following procedure.

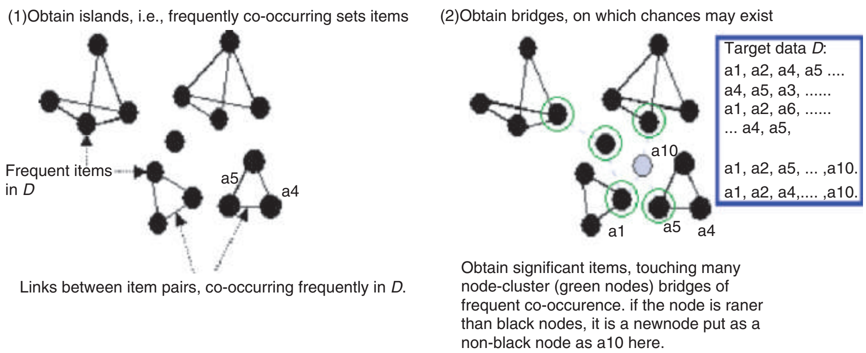

Fig. 3. The procedure of KeyGraph

KeyGraph-Step 1 ((1) of Fig. 3): Words appearing many times in the data (e.g., a4 and a5 in Eq. (1)) are depicted with black nodes, and each pair of these words occurring often in the same sequence unit (between two periods) is linked to each other with a solid line. Each connected graph obtained forms one island, a set of words to occur in a context.

KeyGraph-Step 2((2) in Fig. 3): Items which may not be so frequent as black nodes, but co-occurring with words in more than one islands, e.g., a10 in Eq.(1), are obtained as hubs. A path of links connecting islands via hubs is called a bridge. A hub rarer than black nodes is presented in a different color. We regard words on a bridge as a candidate of key words.

The output of KeyGraph as in (2) of Fig. 3 includes islands and bridges. If D is a document, periods are put at the end of each sentence. Nodes in the result of KeyGraph correspond to a word in D, and an island corresponds to a set of words appearing in the same contexts. Bridges imply the transitions to contexts, i.e., the contextual flow of the document. Even if words on bridges are rare, they may express the essence of the scenarios presented in the document.

4.2 Elicitation of primitive by the multi-dimensional hearing

First, we would like to explain how a requirement primitive is derived from the multi-dimensional hearing. The elicitation process of primitive is monitored by KeyGraph for an example requirement: "We want to utilize video information for a presentation".

[The contents summary of multi-dimensional hearing]

Object level: We utilize video information for a presentation.
  Positive: Video information appeals to user's impression directly.
  Negative: It is difficult to search and allows us only a sequential search.
Purpose level: Why do you use video information for a presentation?

Positive: Video information includes visual information abundantly. Visual information has direct influence on drawing user's empathy.
Negative: Video information is very difficult to search directly, because of the difficulty of encoding the information for indexing
Method level: We use a fast forward function for retrieving video information.
Positive: We can estimate video clips quickly by the fast forward function.
Negative: Intelligibility of sound and reality of time are lost.

The elicitation process of a requirement primitive visualized by KeyGraph is illustrated in Fig. 4.

The requirement primitive elicited by the multi-dimensional hearing is visualized by KeyGraph (Fig. 5).

The primitive consists of 3 layers of requirement: basic claim, purpose and implementation method, and their premises and restrictions between each

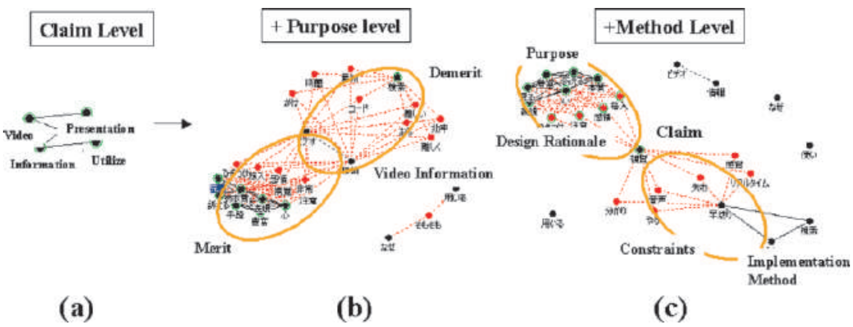

Fig. 4. The growth of primitive visualized by KeyGraph

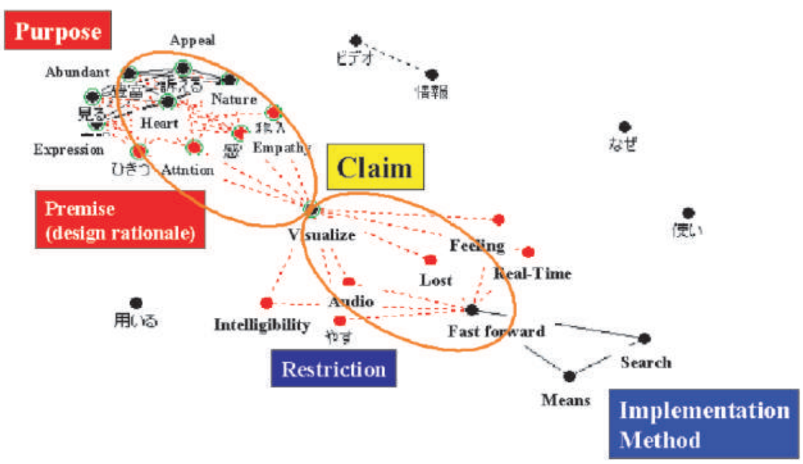

Fig. 5. The primitive derived the from multi-dimensional hearing

layer. The shape of the primitive shows a di-poles structure. The basic claims of the primitive is placed at the center of the di-poles, one pole explains the purpose of the design, and the other pole shows the implementation methods. The bridge between the purpose and the basic claim means premises or design rationale. The other bridge between the basic claim and the implementation method means restrictions for realizing the proposed implementation method.

4.3 Integration of primitives through the hierarchical accommodation process

Let us consider the process of integrating the primitives into requirement scenario through the hierarchical integration process. A lot of primitives are gathered in the inspection test step. Primitive grow in the correlation between primitives in the discussion step.

When two primitives have common purpose, these primitives are connected each other by similarity of the purpose. As a result, these primitives integrated to a requirement scenario where the common purpose and claim are combined by intersection of primitives in Fig. 6(a).

When two primitives have subordination , i.e. the method of a primitive regards as the purpose of the other primitive, these primitives are chained. As a result, these primitives grow like an unified primitive in Fig. 6(b). By the repetitions of intersections and chains in the hierarchical integration process, all the primitives integrate into an unified requirement scenario (Fig. 6(c)).

The basic concept to elicit the requirement scenario through intersections and chains of plural request primitives obtained the way of thinking from the above-mentioned the objectives driven approach in requirements engineering (Fig. 7) [1].

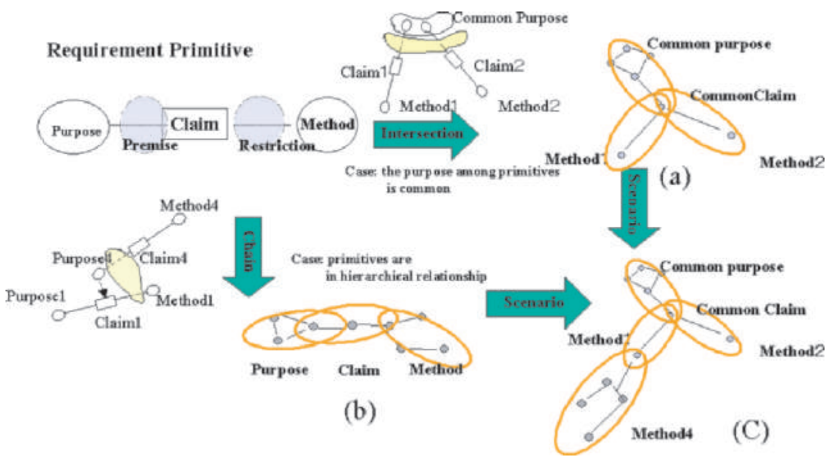

Fig. 6. The growth of scenario by intersections and crossing of primitives

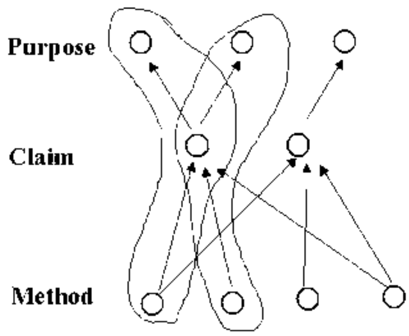

Fig. 7. The concept of the objectives driven approach

5 The experiment of the elicitation of scenario

An experiment of the elicitation of requirement scenario was conducted on the proposed process by using a paper prototype [14] of home controller for household appliances.

5.1 Outline of the experiment

Basic settings of the experiment are shown in Table 2. The experiment was conducted in the process shown in Fig. 2.

The following is the summary list of the experiment steps:

Step 1:

- The package of the documents (The ground rule document and Task instruction document) was distributed to the actors.

Table 2. The basic setting of the experiment

Items	Details
Stakeholders	Representatives of user(3) A representative designer(1) Human Interface design specialists(2) A Moderator(1)
Task	4 tasks for operating of home appliances (ex. Water heater) Task1: Set the temporary temperature of water Task2: Set schedule of machine operation Task3: Set the default temperature of water Task4: Operation when an error occurred
Examination Process of each group	Case1: Conventional inspection test (CIF) process Case2: CIF + the multi-dimensional hearing Case3: Proposed process in the paper

  - Ground rule document: A document describing profiles of users and the concept of the panel design
  - Task instruction document: An instruction document of examination tasks using a prototype. Each task scenario was written in the document and the panels were put together, enabling him or her to write claims and comments directly on the page.
- The designer explains the design concept of the operation panel.
- Each stakeholders write claims and comments on the task instruction document.
- The designer explain the prepared way of the operations.

Step 2:
- The users explain their claims and comments.
- The moderator interviews the users by the multi-dimensional hearing.

Step 3:
- The designer explains her/his claims and comments.
- The moderator interviews the designer by the multi-dimensional hearing.

Step 4:
- The human interface design (HMI) specialists explain their claims and comments.
- The moderator interviews the specialists by the multi-dimensional hearing.

Step 5:
- The users propose improvements.
- The users, the designer, and HMI specialists discuss about the above proposals and create new idea for improvements.
- The moderator interviews the proposal by the multi-dimensional hearing.
- Principle of discussion is that the user representations first.

Step 6:
- The moderator judges that accommodation have been formed, then starts next task.

5.2 The results of the experiment

The results of the experiment are shown in Table 3. Scenario was elicited from every task trough the hierarchical integration process

Table 3. The results of experiment

Items	Case1	Case2	Case3
Task Execution time(minutes)	9	16.6	31
Number of acquired primitives (for each task)	3.4	10.4	32.8
Number of elicited scenarios (for 4 tasks)	0	0	4

6 Evaluation

The proposed method was evaluated by two criteria: the efficiency of eliciting requirement primitives and the contribution to drive integration of a requirement scenario.

6.1 The efficiency of eliciting primitives

It is important to elicit the primitives efficiently in limited time. The results are shown in Table 4. The efficiency of the proposed method exceeded the conventional inspection test about three times.

6.2 Contribution to drive integration of a requirement scenario

The follwing four kinds of requirement scenarios were obtained in the experiment.

Scenario 1: The presentation method of the apparatus list for operation target
Scenario 2: The differences the mental models between users and a designer
Scenario 3: The familiarity of terms used for the label of a button
Scenario 4: The validity of introducing analogies of personal computer operation to home appliances operation

In order to evaluate contribution of the multi-dimensional hearing and the hierarchical integration process toward integrating a requirement scenario, the process for integrating of the scenario-2 in the examination is illustrated in Fig. 8 and the growth of scenario also visualized in Fig. 9.

The requirement scenario was elicited after repeating 3 times of discussion cycles. The multi-dimensional hearing drove to rotate the cyclic process in Fig. 8. The purpose and claim of the primitive were redefined in C1 and C2 cycle. In the step of C3, all the stakeholders understood the purposes, claims and the restrictions and premise of the implementation completely and a lot of implementation method were proposed explosively.

The following is the summary list step by step of each cycle in Fig. 8:

Basic proposal: A basic proposal that some icons on the panel should be changed to make it easier to understand (Fig. 9(a)).

Table 4. The efficiency of eliciting primitives

Items	Group1	Group2	Group3
Time for eliciting a primitive (minutes)	2.6	1.53	0.96

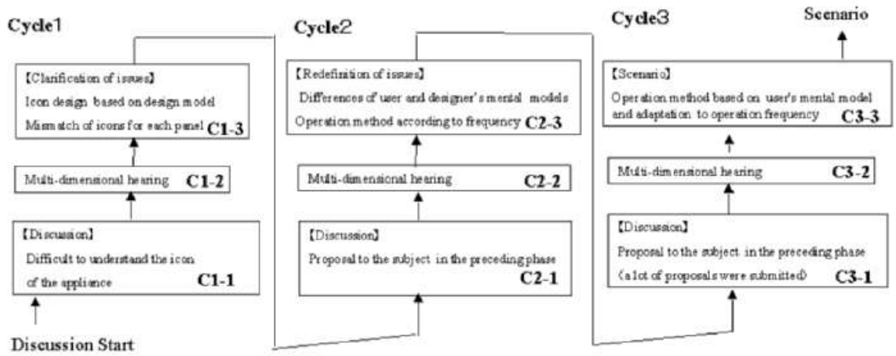

Fig. 8. The effect of the multi-dimensional hearing for rotating cycle of discussion

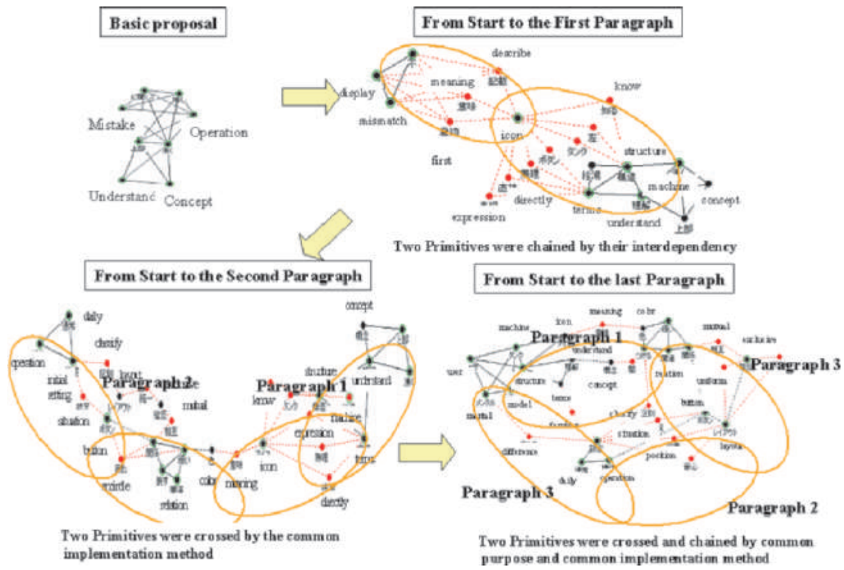

Fig. 9. Growth of scenario 2 visualized by KeyGraph

From the basic proposal to Cycle 1: The causes and the improvements of the difficulty of understanding were derived from the multi-dimensional hearing. Two primitives in hierarchical relationship were chained. The result of KeyGraph shows a di-poles structure (Fig. 9(b)).

From the basic proposal to Cycle 2: The other cause was added. Two requirement primitives newly derived from the hearing were chained by similarity of the implementation method (Fig. 9(c)).

From the basic proposal to Cycle 3: Another two primitives derived from the hearing were intersected and were chained with the common purpose and the common implementation method (Fig. 9(d)).

Consequently, the unified requirement scenario was integrated by the intersections and chains of the primitives through the hierarchical integration process. When a scenario was integrated, the answer to the multi-dimensional hearing was expressed recursively by the terms appeared in the former discussions.

7 Conclusion

The efficient scenario elicitation method has been established by combining the chance discovery and the requirements engineering methods. The method consists of the multi-dimensional hearing and the hierarchical integration process.

We evaluated its capability through the experiment using a proto type of home controller. The following have been confirmed: requirement primitives which consist of its purpose, claim, implementation method, premises and restrictions were elicited by the multi-dimensional hearing; the primitives grew by intersections and chains and were formed into a unified requirement scenario through the hierarchical integration process, the proposed method exceeded the conventional inspection test in the efficiency of eliciting primitives.

We hope that the method will be widely used and open the way to lead us to discovering a chance in requirements analysis.

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ConExSIR: A Dialogue-based Framework of Design Team Thinking and Discovery

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Summary. This research presents a dialog-based framework of design team thinking and discovery that synthesizes an inquiry-based design thinking model and a con-ceptual-exploration process model. The framework is applied in order to code the dialog acts of teams engaged in conceptual design activity, and measure design-team processes related to generating design alternatives and making decisions. Preliminary results highlight relationships between the two models, and support the tentative conclusion that team performance on a conceptual design task is positively correlated with the frequency of a dialogue act termed, "limit-handling." Remaining challenges include fully integrating and validating prior models and validating dialogue facilitation techniques to support conceptual design, decision analysis, and risk analysis.

1 Introduction

Constructing meaningful and useful scenarios of the future is a key aspect of decision making and design[3], as scenarios are instrumental in identifying critical needs and in generating concepts that can meet those needs. In this sense, "meaningful" entails feasibility and relevance to the design task at hand, and "useful" entails the potential for realization to meet needs, create value, or handle risks. Research in the emerging field of Chance Discovery [1] is dedicated to facilitating the development of such scenarios, and team communication is seen as a central factor of this process, which has been called scenario emergence [2].

This paper synthesizes two previously introduced dialogue-based models of team interaction and performance in order to construct a comprehensive research framework that can be applied to analyze, describe, and possibly

[3] In this research, the term "design" is used broadly, and includes all tasks that involve thinking about, creating, planning for, and realizing potential future scenarios.

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predict the outcome of scenario construction and concept generation activities which take place during team discourse. The two dialogue-based models, which are outlined in detail in the following sections, are synthesized as a design-thinking formulation based on "Question-Decision Duality Theory (QDT)" [3].
QDT postulates that:

1. Behind every decision there is a constellation of questions-which are motivated by unmet needs, an intention to influence the future state of the world, uncertainty, and ambiguity-that populates the decision space; hence the questions can be tracked to understand, model and simulate the decision-making process.
2. The corollary is that behind every question there is a constellation of decisions that populate the question space; hence the decisions can be tracked to understand, model and simulate the question-making process.

For innovative scenario construction and alternative concept generation, these processes should not be separated from each other. Unfortunately, separation is the rule in many organizations where the question-making role is assigned to one unit (typically the designers) and the decision-making role to another unit (typically management).

Conceptual Exploration through Structured Inquiry and Reframing (ConExSIR) is a QDT-based formulation of the two dialogue-based models. It provides an essential complement to classical decision theory for practical application to problems of design and decision making, as well as a foundation for further empirical research in these areas. Decision theory is essentially a normative theory of choice, based on the assumption that all relevant scenarios and design concepts have been identified and characterized, but the theory offers no explanation of how this is accomplished. Decision analysts recognize this limitation. For instance, Howard [4] argues that "framing" and "creating alternatives" are critical steps in the decision analysis process, and are essential to ensure that "we are working on the right problem." On framing, he states: "Framing is the most difficult part of the decision analysis process; it seems to require an understanding that is uniquely human. Framing poses the greatest challenge to the automation of decision analysis."

The ConExSIR approach addresses these framing and alternatives generation issues directly by identifying and modeling dialogue processes that reflect essential cognitive mechanisms for arriving at comprehensively explored scenarios and rich sets of alternative design concepts. The approach is designed to capture team interaction in situations where design, decision making, and innovation intersect. Hence, ConExSIR is highly relevant to Chance Discovery research and practice, as well as decision analysis, and it provides a critical augmentation to decision-centric theories of design [5].

2 Synthesis of two Dialogue-based Interaction Models

The two dialogue-based models that form the basis of ConExSIR are the Divergent-Convergent Inquiry-based Design Thinking model (DCIDT), and the Amplex Limit Process (ALP) model.

2.1 Divergent-Convergent Inquiry-based Design Thinking Model

The DCIDT model, derived from data collected in the field and the laboratory, states that inquiry takes place in two fundamental modalities: divergent and convergent questioning [3]. It demonstrates the significance of two classes of questions in design team dialog: Deep Reasoning Questions (DRQs) as defined by Graesser in a learning context [6], and a new class of questions proposed by Eris that are characteristic of design thinking, Generative Design Questions[4] (GDQs). It identifies the incidence of DRQs in design team discourse as a manifestation of convergent thinking, and the incidence of GDQs as a manifestation of divergent thinking. The key distinction between the two classes of questions is the truth-value of the propositions that can be offered as answers. By definition, the answers to DRQs are expected to hold truth-value, whereas the answers to generative design questions are not. DRQ's imply truth-value because their answers fundamentally depend on causal relationships established in prior knowledge, while GDQs do not imply truth value because their answers fundamentally depend on subjective perception of future possibilities.

According to the DCIDT model, effective inquiry in engineering design thinking entails both a divergent dimension in which GDQs are asked to create, synthesize, and expand concepts, and a convergent dimension in which concepts are analyzed, evaluated, reduced, and validated by systematically asking DRQs. The significance of this complimentary relationship is supported by the discovery of a correlation between the combined incidence of DRQs and GDQs and design performance of engineering teams during a design exercise [3].

Building on these findings, DCIDT describes a structure for design thinking. The model illustrates that high performance design teams realize the importance of managing ambiguity, and use the GDQ and DRQ mechanisms in a balanced fashion to operate at the appropriate level of conceptual abstraction throughout the design process. The resulting design thinking model illustrates the transformation of design requirements into design concepts through GDQs, and the transformation of those concepts into design decisions and specifications through DRQs.

[4] Greesser's DRQ definition, and Eris's GDQ extension are both based on Lehnert's taxonomy of questions [7]. 5 of Lehnert's original 12 question categories were termed deep reasoning questions by Graesser [6]. Eris proposed 5 new question categories as extensions, and termed them generative design questions [3].

2.2 Amplex-Limit Model

The Amplex-Limit Process (ALP) model was developed initially based on observations of decision making in organizational settings, participation in decision analysis cases, and a review of prior work on dialogue in artificial intelligence, the philosophy of language, and decision consulting [8, 9], and has been refined based on analysis of design-team dialogue. By modeling *conceptual exploration* as a dialogue process based on a small set of *dialogue-acts*, the ALP model addresses the role of team communication in the framing of decisions and the discovery of alternatives in both decision making and design. Dialogue-acts are types of utterances that play specified roles in dialogue, sharing certain kinds of information among the participants, reflecting intentions of the speakers and relationships between utterances [10].

The term *Amplex-Limit* combines the words *amplify*, *explore*, and *limit*, three key dialogue-acts of the ALP model. *Limits* are dialogue-acts reflecting our perceptions, assumptions, inferences, and judgments that arise explicitly in conversations, in response to the introduction and elaboration of concepts. Note that here a limit, defined as a dialogue-act, is an observable behavior and not a cognitive state, psychological perspective, or physical or social condition. The term "*Amplex*" also derives from the Latin *amplexus*, meaning, "embraced" or "surrounded." This term motivates the connotation that our perceived space of actions and possible futures is surrounded, or delimited, by *limits*, and the notion that these *limits* collectively constitute a type of *frame* that embraces concept development activity as it is reflected in dialogue processes.

The ALP dialogue-acts represent the central operations involved in establishing and searching a concept space [8, 9]. During the search, concepts are introduced, developed, and evaluated. Knowledge, which is subject to later revision, is accumulated as the search proceeds. The exploration of the concept space is performed by the use of the following six operators, employed in dialogue acts, and yielding a network of concepts and conceptual relations:

- *Introduce*: (INT) Brings into the dialogue a new concept, generally, which constitutes some aspect of a product design, future action, event or scene; new decisions and uncertainties enter into the dialogue.
- *Amplify*: (AMP) Elaborates upon the nature, aspects or functions of a previously mentioned concept, generally, by adding attributes and attribute values; adds detail; elaborates on the characteristics of previously considered decisions and uncertainties.
- *Explore*: (EXP) Generates or derives a new concept (or concepts) by varying aspects of previously mentioned concepts, or by combining concepts; creates a wider span of perceived decisions and uncertainties.
- *Limit*: (LIM) Excludes or "rules out" a concept or a set of concepts, generally, based on certain attributes or characteristics of the concepts. *Limits* have two forms: first, *negations*, or *direct exclusions*, which contain or imply words such as "no" or "not"; second, *anchors*, or *indirect exclusions*,

which contain or imply words such as "must" or "have to" or "only." *Limits* generally entail a limiting assertion regarding possibility, relevance, control, influence, value, or process, that tends to reduce the span of decisions and uncertainties considered worthy of further discussion in a specific design or decision-making context. *Limits* are often accompanied by *support*, which provides reasons for, or the basis of, their declaration. *Limits* are *unconditional* propositions; conditional propositions involving negation or anchoring generally constitute *limit-handling* acts.

- *Limit-Handling*: (LH) To implicitly or explicitly question, challenge, qualify or condition a *limit*. If the challenge results in retraction or revision of the *limit*, then a wider span of decisions and uncertainties may be considered worthy of further discussion.
- *Return*: (RET) To redirect attention back to a previously mentioned concept for further *amplify*, *explore*, *limit*, or, *limit-handling* operations.

The philosophy underlying the ALP model entails the following assumptions: 1) The basic functions of language are to represent, process, and share information [11]; 2) The basic information contained in an utterance can be represented as a *conceptual structure* or *conceptual graph* [12, 13]. These simplifying assumptions downplay interesting and important aspects of linguistic interaction, for example, cultural, social and psychological factors. As Sowa observes, key aspects of meaning may be ignored, such as emotional connotations and the meaning conveyed by tense, aspect, and mood. In spite of these simplifications (and also in part, due to them), the ALP is a practical model of team interaction that effectively captures central characteristics of the conceptual exploration process, since each ALP dialogue-act can be precisely and computationally defined by its effect on a conceptual structure.

The propositions embodied in *Limit* (LIM) and *Limit-Handling* (LH) acts reveal aspects of the actors' *frames*. A *frame* can be thought of as a person's perspective on a situation, that filters what is relevant while guiding inquiry, action, and decision making [14, 15, 16, 17, 18]. *Limit-Handling* (LH) acts reflect the *re-framing* of the conceptual exploration process based on knowledge shared and developed by the participants. The view that *frames* and *framing* are embodied in these dialogue acts (LIM and LH) is not intended to downplay the significance of implicit social and psychological aspects of frames. These dialogue acts are of key importance in establishing and managing frames, and provide an empirical basis for understanding the interrelationship of framing, decision making, and discovery [19].

2.3 Conceptual Exploration through Structured Inquiry and Reframing: ConExSIR

A QDT-based formulation of the DCIDT and ALP models resulted in the ConExSIR approach, in which an inquiry-based design thinking model was augmented by considering it in conjunction with the principles of the ALP model. ConExSIR is intended to serve as a complimentary approach to traditional decision-theoretic design thinking, and if developed further, might provide a basis for proven facilitation techniques for the development of innovative and useful concepts (e.g., decision alternatives, design concepts, scenarios, risks).

The working hypothesis of ConExSIR is that DCIDT and ALP models, although they are derived from distinct sets of principles and theories, both attempt to explain and operationalize the same phenomenon-the conceptual expansions and contractions that occur during dialogue. It follows that the question categories put forward in DCIDT would be relevant to the dialogue acts put forward in ALP. Therefore, the main goal of the research presented in this paper is to:

1. Test the above working hypothesis by exploring the potential relationships between the DCIDT question categories and the ALP dialog acts.
2. Characterize any relationships that can be identified.
3. Test to see if such relationships are related to the outcome of the team interaction they are extracted from, such as design performance and discovery making.

More specifically, ConExSIR postulates that two dimensions of design team interaction can be characterized by counts of DCIDT question categories and ALP dialogue acts. Together, these two dimensions characterize a team's approach to a process we call "conceptual exploration."

The first dimension of conceptual exploration is *concept development*. From an ALP perspective, it involves introducing and amplifying concepts (INT and AMP acts), and generating new concepts from those previously introduced (EXP acts). From a DCIDT perspective, it reflects predominantly divergent thinking, and involves asking of generative design questions (GDQs).

The second dimension of conceptual exploration is *framing*. From an ALP perspective, it involves asserting limits (LIM acts) regarding the scope, feasibility, effectiveness and desirability of concepts discussed, and questioning or challenging *limits* (LH acts) to reframe the concept development activity. From a DCIDT perspective, it reflects predominantly convergent thinking, and involves asking of deep reasoning questions (DRQs).

Finally, ConExSIR also postulates that high performance design teams make relatively more LH and EXP moves than low performing teams, based on the view that these acts are associated with a higher level of knowledge sharing and collaborative learning than the other acts (INT, AMP, and LIM). Note that a strong positive correlation between the combined incidence of DRQs and GDQs and design team performance has been demonstrated already [3].

3 Data Collection and Analysis

QDT was derived from empirical observations of design teams in the field and the laboratory. Since ConExSIR is a QDT-based formulation, data that were collected in the laboratory experiment and used in the development of QDT served as a good starting point for testing the ConExSIR hypothesis outlined in section 2.3.

3.1 Description of the Dataset

In the original experiment, thirty-six designers, in teams of three, were videotaped while engaged in a design exercise, and video interaction analysis was performed in order to identify and characterize the questions that were asked [3]. The teams were given 90 minutes to complete their task, which was to design and prototype (from a standard set of Lego parts) a functional instrument for measuring the length of body contours, a "bodiometer." For reasons that are not relevant to this discussion, half of the teams (six out of twelve) were given the parts kit after an initial planning period of approximately 30 minutes, whereas the other half were given the parts kit at the start of the exercise.

The data and analyses from this prior work were available, including performance scores, incidence of the types of questions that were asked within team discourse, and incidence of discoveries that were made. Dialogue from the video tapes of the six teams which did not receive any prototyping hardware during the initial 30 minutes of the experiment was transcribed and re-analyzed in order to identify ALP operators. Video tapes of the other six teams were not analyzed because the presence of hardware influenced the dialog in such a way that the use of the ALP operators was impacted; non-verbal communication increased dramatically with the use of physical artifacts. This was unfortunate for the purposes of this study since it resulted in a smaller sample size, and subsequently, limits the generalizability of the findings of the initial analysis presented in the following sections. From the transcripts of the six teams, relationships between the incidence of GDQs, DRQs and ALP operators was studied, as well as the relationships of these acts to design team performance and discovery making.

3.2 ALP Operator Coding Scheme Reliability

In order to draw conclusions from coded dialogue data, it is essential to establish a reliable dialogue act coding scheme. Inter-coder reliability tests for the identification and categorization of the questions that were asked during team discourse were conducted, and the results were found to be satisfactory as a part of Eris's previous work [3]. As a part of this research, initial attempts to code dialogue based on the ALP dialogue acts resulted in a reasonably high percentage of agreement among coders regarding occurrences of particular dialogue acts. However, the reliability of the coding scheme, as measured by kappa, was not found to be satisfactory. Kappa is defined as: $[P(A)-P(E)]/[1-P(E)]$; where $P(A)$ is the percent agreement between coders, and $P(E)$ is the probability of agreement due to random chance. Kappa is a

Table 1. Inter-coder reliability for coding the ALP dialogue acts.

ALP Act	P(A)	P(E)	Kappa
INT	97%	95%	0.45
AMP	78%	56%	0.49
EXP	92%	86%	0.44
LIM	95%	90%	0.43
LH	99%	98%	0.75

more appropriate (and more stringent) measure of reliability than P(A) [20], since it corrects for expected agreement due to chance.

Table 1 shows results of the initial inter-coder reliability test. Two researchers coded the same 294 dialogue acts for one of the teams. P(A) shows the percentage of agreement between the coders regarding the presence or absence of dialogue acts within a given utterance. P(E) shows the percentage inter-coder agreement expected due to chance. The values shown for P(E) may appear surprisingly high, but since any given ALP act is relatively infrequent, coders might often agree by chance that an act did *not* occur. In general, for acts that occur less than 50% of the time, the less frequent is the act, the higher is P(E). For the relatively infrequent acts of the ALP, P(A) must be extremely high for kappa to approach 1. Note that for the LH acts, which occurred only rarely, better than 99% agreement between coders resulted in a kappa of only .75. This may appear low when compared to percent agreement, but kappa provides a measure of agreement that has been achieved *above and beyond* what would be expected due to chance agreement[5]. To attain a higher level of inter-coder reliability, detailed coding definitions and a coding decision scheme, following the method of Krippenford [20] were subsequently developed, and the entire data set was recoded. Subsequent analysis confirmed that the findings described in the next section are not sensitive to any limitations in intercoder reliability, and are robust regardless of any coding discrepancies that were observed.

4 Results

Two measures were used to judge the level of team performance on the full 90-minute bodiometer design task: the performance of the prototypes of the designs the teams constructed during the experiment, and the number of discoveries made by the teams during the experiment. The first measure is external to the activity, an outcome, whereas the second measure is internal to the activity, a descriptor.

[5] The values for P(A) and P(E) were rounded for the table. The values of kappa shown in the table were calculated prior to rounding P(A) and P(E).

Performance of each design team was measured by an objective scoring scheme that was a function of how well the prototypes met given design requirements, which accounted for precision, usability, manufacturability, and cost [3]. A subjective scheme where three engineering professors rank-ordered the prototypes yielded correlate scoring outcomes, $r^2 = .55$, $p < .01$.

A discovery was defined as an instance during team interaction where a realization that leads to a unique and previously unthought-of concept, or obstacle, related to the design task was experienced. This method is somewhat similar to judging the effectiveness of a brainstorming session based on the quantity of ideas generated. However, it differs in the sense that it requires a higher and more visible degree of conceptual continuity and progression.

Approximately 50% of the speaker turns could be coded with the ALP model. Virtually all dialogue acts pertaining to the design configuration or performance were accounted for, either by the ALP acts, or by the taxonomy of GDQs and DRQs, or both. The other acts were either unclear, or did not pertain to the design. A substantial portion of the un-coded acts pertained to the real-time team process or to the rules of the experiment (e.g., "How much longer should we work before requesting our parts kit?").

Figure 1 depicts a 'dialogue style graph' characterizing the *conceptual exploration* processes for each design team, and illustrates how the ALP dialogue-act counts can be used to qualitatively differentiate design teams with respect to relative levels of *concept development* and *framing* activity. The radar graph has four rays, two rays per dimension. Each ray represents a metric of design team activity. The sum of INT and AMP acts is charted on the upper ray, and the count of EXP acts is charted on the lower ray. These rays constitute the *concept development* axis (vertical). The counts of the LIM and LH acts are charted on the remaining two rays, which constitute the *framing* axis (horizontal).

The graph depicts the dialogue style for each of the six teams. To show the basic trend relating dialogue-style to team performance, the graph for the highest-performing team, and the graph for a low-performing team are shown in heavy solid lines. Note the graph of the highest performing team tends to subsume the graphs of the lower performing teams. However, strong statistical trends relating dialogue-style to team performance applied most significantly *not* to the graph as a whole, but only to the excursion of the graph into the lower right quadrant, i.e., to the counts of LH and EXP acts, as described next.

As described in Section 2.3, ConExSIR postulates that the teams with the highest performance scores would have relatively more LH and EXP acts (the lower-right quadrant of the dialog style graph) than the low performers, and that the lower performing teams would have relatively more LIM and INT+AMP acts (the upper left quadrant of the dialog style graph). To test this hypothesis, the following dialogue style-metric was defined: (EXP) x (LH), the product of the counts of EXP and LH acts that occurred during the interaction period. The product, rather than the sum, was used in order

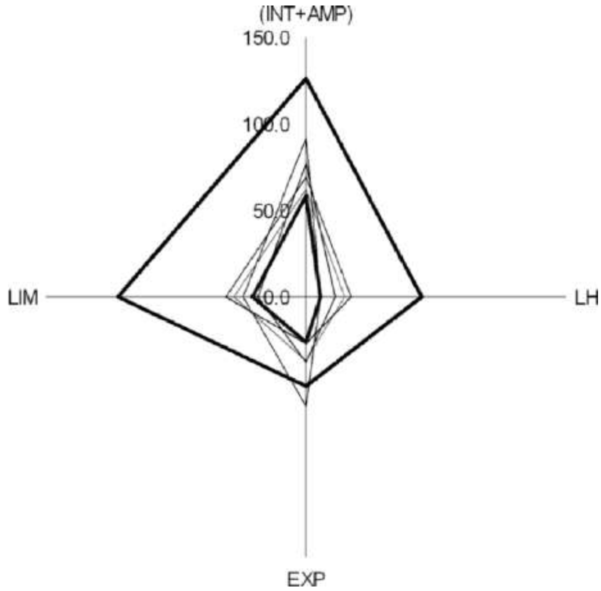

Fig. 1. Dialogue style graph characterizing *conceptual exploration* in two dimensions - *concept development* (vertical) and *framing* (horizontal).

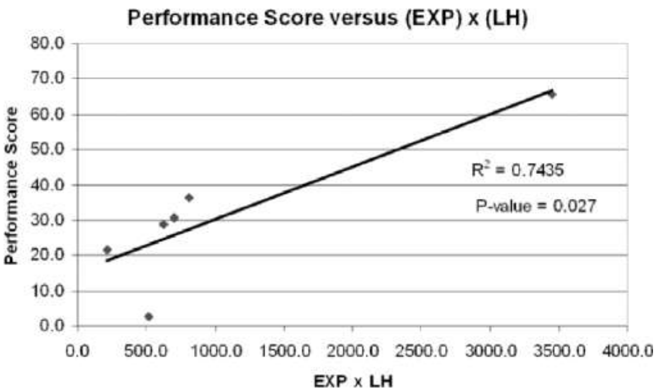

Fig. 2. Team performance versus the dialogue style metric (EXP) × (LH).

to reward balance between these two distinct types of acts, and to penalize heavily for the absence of either act. There was a significant correlation between this style-metric and team performance. Note that Eris [3] had previously found a significant correlation of team performance to the combined incidence of generative design and deep reasoning questions (GDQ+DRQ) for the entire duration of the experiment.

Due to limitations in the reliability of the initial coding attempts, reliable distinctions between the acts of the vertical axis of the dialogue style graph could not be made. This led to the test of the partial hypothesis that performance should be positively correlated with the incidence of LH acts (excluding the EXP acts). In the initial analysis, a strong correlation of LH acts to team performance was found, and based on those preliminary findings, this relationship was tested again after the entire data set was recoded according to the refined coding criteria. Figure 3 shows the final results: team performance is strongly and significantly correlated with the count of LH acts during the first 30 minutes of the interactions. In fact, the dialogue style-metric obtained by a simple count of LH is the strongest ALP-derived correlate of team performance.

Figure 4 shows a positive correlation between LH acts and DRQs, and Figure 5 shows a similar correlation with GDQs. This suggests that LH acts and DRQs and GDQs may measure the same underlying cognitive phenomena with different operationalizations. An alternate explanation is that incidence of DRQs, GDQs, and LH indicate highly correlated underlying cognitive phenomena. This correlation is important because the definitions of LH, DRQs, and GDQs are constructively different. In other words, DRQ, GDQ and LH are not simply different labels for the same behavior, but represent distinct behaviors that may correspond to similar underlying cognitive activities. LH acts are much more frequent than DRQs-the LH/DRQ ratio is approximately five to one DRQ, so the measure is more readily obtained in a smaller sample.

Figure 6 shows a positive correlation between limit handling (LH) acts and the number of discoveries made throughout the entire duration of the experiment.

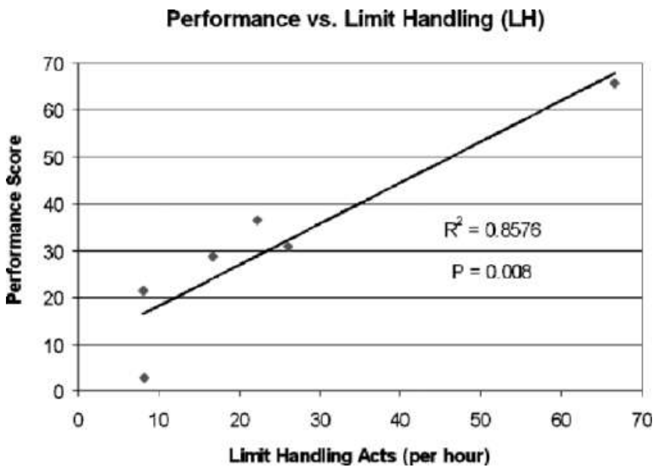

Fig. 3. Design team performance score is positively correlated with *Limit-Handling* (LH) acts.

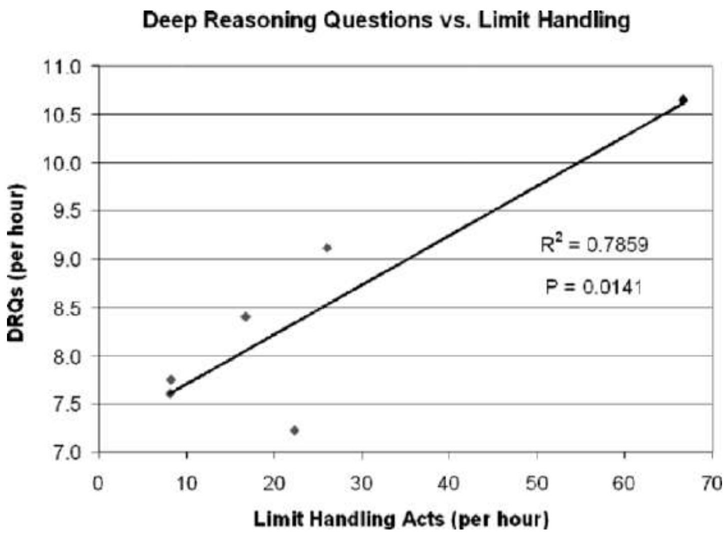

Fig. 4. DRQs are positively correlated with *reframing* acts (LH).

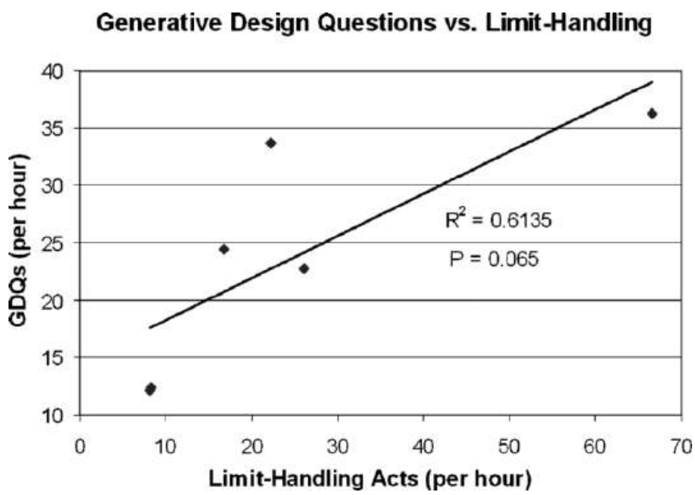

Fig. 5. GDQs are positively correlated with *reframing* acts (LH).

Figure 7 shows a positive correlation between LH acts and LIM acts. For every team, the count of LIM acts exceeded the count of LH acts, on average, by a ratio of approximately three to one. In all teams, only a fraction of limits were challenged or questioned.

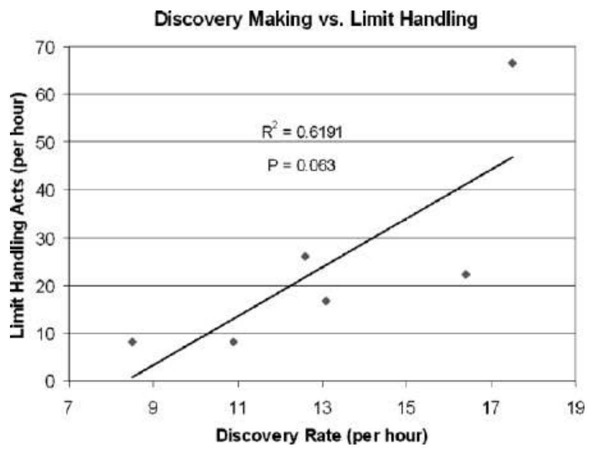

Fig. 6. *Reframing* (LH acts) is positively correlated with *discovery making.*

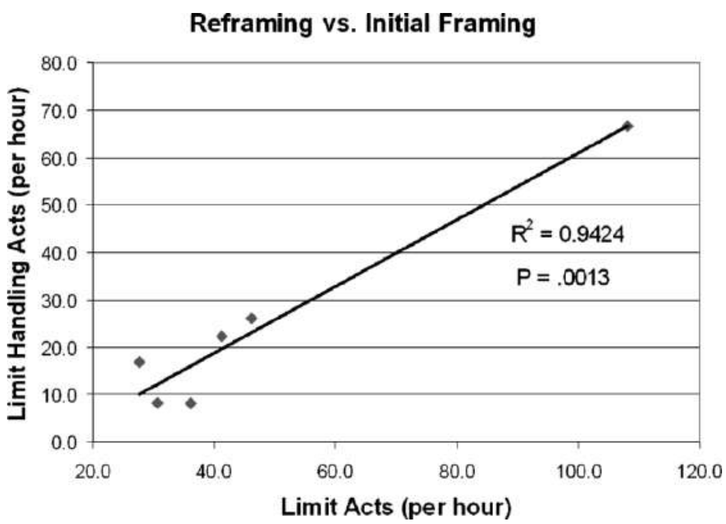

Fig. 7. *Reframing* (LH acts) is positively correlated with *initial framing* (LIM acts).

5 Discussion and Conclusions

LH acts were found not only to correlate positively with design team performance and discovery making, but also with LIM acts, DRQs, and GDQs. Therefore; firstly, it can be concluded that the two dialog-based models embodied within the ConExSIR approach are indeed related, which is the working hypothesis of this work; secondly, that *reframing* acts (LH) appear to constitute the canonical connection between the two models.

When considering the hypothesis regarding the specific mapping between the DCIDT categories and ALP acts, as articulated by *concept development* and *framing* dimensions of ConExSIR in Section 2.3, it appears that a simple mapping between the models might not exist. Reframing, as embodied in LH acts correlates to some extent with both DRQs and GDQs, though the correlation with DRQs is stronger and more significant, and LH also correlates strongly with LIM acts. We hypothesized the relationship of LH to DRQs and LIMs, but the correlation with GDQs was unexpected.

The relationship between LH and the question types appears to be a dynamic one, possibly characterized by a complex network of cause-effect relationships between the cognitive activity associated with the question types, the questions themselves, and the LIM and LH dialogue acts. Consider the following sequence as a simple example: Convergent thinking manifests in DRQs $\rightarrow$ DRQs result in LIM acts $\rightarrow$ LIM acts result in LH acts $\rightarrow$ LH acts result in divergent thinking manifesting in GDQs. This is one of many tight causal sequences that could be hypothesized for these dialogue acts, to explain the observed correlations in the data. The relationships are potentially so dynamic that simple dialogue act counts are highly unlikely to capture them–further qualitative analysis is required. If such a tight causal network indeed exists in high performing teams, then this interpretation supports Eris's original hypothesis and findings, regarding a "requisite balance" of DRQ and GDQ in effective design team inquiry processes [3].

The return operator (represented by RET dialogue acts) was included in the ALP model based on theoretical considerations as well as field observations. An effective dialogue for generating and evaluating concepts should have many branches, or conversational threads, since ideas that surface in relation to a given concept can be highly relevant to prior concepts. Therefore, it is reasonable to hypothesize that a team should, as a rule, notice and question such connections, returning to prior conversational threads to further develop concepts that came up before, based on new insights and knowledge that surface as the dialogue proceeds. In qualitative analyses of the data, interrelations between GDQs and RET acts were observed. However, the RET act has not been identified with the necessary precision to achieve high inter-coder agreement regarding its occurrence, and conditions under which any rule would apply have not yet been established. Therefore, these issues constitute future work.

We note that Graesser and Person [21] found that the occurrence of DRQs correlates positively with student learning when comprehending concepts in scientific texts (as measured by an examination score), while we found that the frequency of LH acts (*reframing*) correlates positively with team performance (as measured by scoring the design produced). Since LH acts also correlate positively with DRQs as well as LIM acts, it would be useful to formalize the relationship of *framing*, *reframing* and *learning* by a team, and to use this formalization as a basis for future empirical work.

The long-term goal of this line of research is to integrate the ALP and DCIDT models within the Question-Decision Duality Theory (QDT) framework, in particular, to relate the DRQ and GDQ question categories to the dialogue acts of the ALP. Such an integrated model would have the potential to provide a theoretically and empirically sound basis for team facilitation techniques, as well as information technologies to support team interaction, based on semantically precise dialogue models. Thus, the ultimate goal of this work is to produce and validate *prescriptive* models of process interventions. The work described in this paper-toward *descriptive* validation-is undertaken to ensure the evolving model is well grounded, and that any interventions ultimately based on it are indeed workable. Since conceptual exploration, inquiry, and reframing are fundamental aspects of scenario emergence in team communication, validated interventions and technologies based on this work could find wide applicability in fields that rely on scenario emergence, such as conceptual design, decision making, future studies, risk analysis, and chance discovery.

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Chance Discovery in Credit Risk Management - Estimation of Chain Reaction Bankruptcy Structure by Chance Discovery Method

Shinichi Goda*

Summary. Credit risk management based on portfolio theory becomes popular in recent Japanese financial industry. But consideration and modeling of chain reaction bankruptcy effect in credit portfolio analysis leave much room for improvement even though the importance of the effect is recognized among credit analysis experts. That is partly because method for grasping relations among companies with limited data is underdeveloped. In this article, chance discovery method is applied to estimate structure of industrial relations that are to include companies' relations that transmit chain reaction of bankruptcy. The steps for the data analysis is introduced and result of example analysis with Japanese default events data of 2005 is presented.

1 Credit risk management based on portfolio theory

Credit risk management based on portfolio theory becomes popular in recent Japanese financial industry promoted by introduction of BIS regulation and increasing use of model-based loan decision making.

Simulation method comes to be common tool for analysis of credit portfolio. Simulation models have been developed for credit risk management and simulators based on these models have been used in actual finance business [1, 2, 3, 4].

2 Effect of chain reaction bankruptcy

Although these models and simulators have progressed since 1980s, there still remain major areas for improvement. Analysis on chain reaction bankruptcies is one of these areas. General definition of chain reaction bankruptcy is like "bankruptcy triggered by a preceding default of a company that has trade and other relations with the bankrupting company"

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Chain reaction bankruptcies are common phenomenon. Recent examples in Japan are ones caused by the default of *Maikaru*, a large supermarket, in 2001 and by that of *Sato-Kogyo*, a civil engineering and construction company, in 2002. Most of managers and professionals regard it necessary to take the effect of chain reaction bankruptcy into accounts when they analyze profile of their credit risk portfolio - degree of concentration of credit i.e.

By introducing chain reaction factor into bankruptcy forecasting and credit portfolio analysis, we can expect:

(1) to capture chance of default sooner by using the default of other companies as leading indicator.
(2) to better grasp the risk profile of credit risk portfolio since amount of loss caused by default of a company can be larger if there are other bankruptcies triggered by the default.

However, majority of simulation models actually used in business field today do not fully take the chain reaction factor among individual companies into account. That is mainly because it is difficult to directly grasp relations among companies since available data that directly shows the relations is very limited. The reasons are:

(1) Background information about bankruptcies publicly available is very limited, and it is not organized in way that can be used for statistical analysis on cause of chain reaction bankruptcy.
(2) Corporate data related to relations among corporation is very limited to public. Information related to Keiretsu - share holdings, board members, i.e. - is rare example of public data with actual numbers. Few companies make trade, financial and technological relations public, but very few with numbers.

3 Current methods to grasp relations

Adjustments have been devised in models and simulators to include relation effect, but there is much room for improvement. A major method to take the effect into account is to grasp relations among companies by measuring co-relations among movement of the security price of the companies (In this method, a company's security price is regarded as representative of default probability of the company). But this method is applicable only to companies that issue securities. Companies that issue securities are relatively large size and the number is small. On the other hand, most of the companies in a credit risk portfolio are small-mid size and non-security-issuing companies.

Another way is to make industry groups represent companies that belong to the groups, and to estimate relations among companies by grasping relations among the industry groups. Security prices are also used to grasp relations. Co-relations are measured among indexes of securities issued by companies in the industry groups. The measured co-relations are applied to companies that belong to the industry groups. In this method, the measured co-relations are applied not only to security-issuing companies, but also non-security-issuing companies. In this method, relations among non-security-issuing companies are assumed to be same as those among security-issuing companies, if these companies are in the same industry. This is rather strong hypothesis.

The idea to estimate relations among companies by grasping relations among the industry groups is reasonable, as is explained in latter section. However, the idea to estimate relations among companies/industries with co-relations among security prices seems to be unreasonable. Since the most of Japanese companies are non-security-issuing ones, and there does not seem to be enough evidence that support assumption that industry relations among security-issuing companies are same as that of small-mid size companies.

4 Grasp chain reaction bankruptcy structure by chance discovery method

In this article, I propose a method that detects relationship among bankrupted companies, without direct information of trade relations, by chance discovery method. (The basic idea of this method follows the method that used for the chance discovery of earthquake by Ohsawa,Y.[5, 6]).)

In this method, I estimate trade and/or other relations among industry groups in a geographical area by using key graph to visualize relations of industry groups that include companies that defaulted in a certain geographical area within a certain time period.

This method is based on the assumptions as follows;

(1) There should be certain relations that transmitted factors causing defaults among companies that defaulted in a certain geographical area within a certain time period.
(2) Those default transmitting relations among companies should be mainly based on and represented by relations among industry groups. As seen in the above mentioned definition of chain reaction bankruptcy, "trade relation" is generally regarded as the one of the most influential factors of chain reaction bankruptcy. And trade relation between a pair of industry is generally universal among companies in the paired industries.
(3) Default transmitting relations among industries could be paths to transmit default of a company in an industry to other companies in other industries.

Suppose that cloth retailer A and cloth wholesaler B defaulted within a month successively in Kansai district. In another month, cloth retailer C and cloth wholesaler D defaulted within a month successively in Kanto district. Suppose other sets of cloth retailer and wholesaler those located in same districts defaulted successively within a month repeatedly. We can estimate with high confidence that there were sets of trade relation between the cloth retailer and the wholesaler defaulted successively and that the sets of trade relation between the two companies caused the successive default, even if there is no public information of sets of trade relations between the two companies.

We can estimate so based on knowledge about cloth trading industry that cloth retailers buy cloths from cloth wholesalers in general and on the observed fact that the sets of a cloth retailer and a cloth wholesaler those located in a same region defaulted in succession repeatedly.

We can then use the patterns of relations among industry groups that was confirmed and/or discovered by using key graph with defaulted companies' data. These relations are used to better detect change of default probability of a company in an industry after a default of a company in another industry. If a cloth retailer in Tohoku region defaults, for example, we will better assume that the default probability of cloth wholesalers in Tohoku area will be higher.

5 Methodology

Steps to visualize and estimate relations that transmit bankruptcy event among companies by using key graph with defaulted companies' data are as follows (see Table 1);

Step 1. Preparation of data

Prepare data to be analyzed as follows;

(1) Collection of defaulted companies' data: each default event has attributes of default date, geographical area in which the company is located and industry to which the company belongs.
(2) Sorting: group the collected data by area and sort the default events in an each area by order of their default dates.
(3) Select companies that seemed to have triggered chain reaction: select companies those size or impact of default are distinctively larger than those of others as tentative companies those seemed to have triggered chain reactions.

Step 2. Transformation of company data to industry data

Transform company data collected and sorted in Step 1. to industry data by replacing a company's name to a code of an industry to which the company belongs. This is to detect relations among industry by regarding an individual company as a sample of an industry to which the company belongs.

Step 3. Transformation of data to sentence form

Transform the data of Step 2. to sentence form.

(1) Put the default events grouped by area in sentence form by the order of the default date. Each event is denoted by industry name and spaced.
(2) Form one sentence starting from a triggering company that tentatively selected in Step 1-(3) and ending at a company whose default date is after, by certain time period, the default date of the starting company. The time period between a starting default event and an ending one should be properly set so that one sentence contains candidates of default events triggered by a default event that starts the sentence. The period between the starting default event and ending one should be set equally among sentences and should not be too long to lessen the default event that are not directly caused by the starting event.

Step 4. Discovery of relations among industries by key graph

(1) Extract co-occurrence of default events by using key graph with sentences formed default data. An extracted co-occurrence represents a relation between a set of industries those include co-occurred default events.
(2) Interpret a result of key graph and estimate relations among industries. It is important to read relations expressed in a key graph and adjust it if necessary with judgment of human.

Exclude nodes those seem to be mistakenly detected and add nodes those should have relations with others by using experts knowledge. If there are nodes and links those cannot be explained by experts' knowledge, those nodes/links might be mistakenly extracted by chance and might better be excluded. But sometimes, those might indicate relations that have newly founded and are waiting for further interpretation. Examples of experts' knowledge about factors that are supposed to work behind relations extracted by key graph are as attached below.
Factors;

a. Technological and business relations among industries
   - An automobile is made of steel, glass, tires and electronic parts.
   - Most of cloth retailers buy cloth from cloth wholesalers. i.e.
b. Commonality of customers among industries
   - Consumers living in Kyushu region shop at cloth/food retailers and eat restaurant both located in Kyushu.
   - Most of major construction companies in Hokkaido have business with cities and towns in Hokkaido. i.e.
c. Ownership relation:
   - A parent company often has influence over business of its subsidiaries. It is often the case that most business of a subsidiary comes from its parent company and that funding of a subsidiary is supported by its parent company.

6 Case Study - Analysis of chain reaction structure of bankruptcies in 2005

As a case study, I applied the method described above to a data of bankruptcies in Japan, 2005. The contents of data are as follows.

6.1 Contents of data

(1) Samples are about 3,400 companies randomly selected from the all defaulted companies that defaulted based on bankruptcy laws and published in the official gazette in Japan, 2005.
(2) Attributes of a sample are default date, area it occurred and industry to which the bankrupted company belongs. The area consists of 9 districts - Hokkaido, Tohoku, Hokuriku, Kanto, Chubu, Kinki, Chugoku, Shikoku and Kyushu. Samples are categorized in about 200 mid-level industry groups by author, based on the industry categories defined by Teikoku Databank, Ltd.
(3) Tentative companies those seemed to have triggered chain reaction are selected from the companies those listed by Japanese Small and Medium Enterprise Agency as possible source of chain reaction bankruptcy of 2005 (∗). About 100 tentative trigger companies are selected from the list.
(∗) The list is made for the application standard for a public credit facility. Small and medium enterprises that have accounts receivable to the companies on this list can apply for the public credit facility that aims to protect SMEs from chain reaction bankruptcy. The criteria of listing are not made public, but the default sizes of listed companies are distinctively larger than those of not-listed ones.
(4) The time period between a starting default event and an ending one is set as one month. The number of defaulted companies in one month is about 50.@One month period is set to extract direct relation between default events and to make a sentence not too long to get good result with key graph.

6.2 Profile of trigger companies (Table 3)

Before using key graph, I reviewed the profile of tentative companies those seemed to have triggered chain reaction to establish hypothetical scenario to be examined by using key graph.

In general sense, it is expected that business relations are strong among companies dealing goods and services in same categories. It is also expected that, retailers buy goods from wholesalers and wholesalers buy goods from manufacturers. Thus, it is expected that relations among default events are more distinctive among industries that deals goods/services in a same category than those of in different goods/services. It is also expected that default events in industries close to downstream of a business have more distinctive relations with upstream industries of its business. That is, the industry profile of the tentative trigger companies is supposed to be reflected in the default relations among all default events.

The tentative triggering companies are roughly categorized in four groups by the industry they belong - construction related group, consumer goods related group, business goods related group, leisure industries (hotels and golf courses) and other services group. Construction related group consists of civil engineering/construction industries, civil engineering/constructing related goods wholesaling and manufacturing industries. In civil engineering/construction related group, civil engineering/construction industries are equivalent to retailing industries of consumer/business goods. Consumer goods related and business goods related group also consist of retailing, wholesaling and manufacturing industries of each good.

Among them, the number of companies in civil engineering/construction industries is 36 and is by far the largest. The numbers of companies in each of consumer/business goods retailing/wholesaling industry are all less than ten and each industry consists of many small sub-industries. Thus, the impact caused by the defaults of companies in civil engineering/construction industries is assumed to be much more distinctive than those caused by companies in other industries.

6.3 Analysis

First, the data was analyzed on the whole, and then analyzed by sub-groups. (See Table 3 for reference of industry code - name.)

(1)Whole data (Figure 1)@- Overall Image

There is a group of black nodes linked together - C59, C62, C63, C76, C77, W03, W08, W11. Nodes numbered C50s, C60s and C70s represent companies that belong to civil engineering/construction industries. Nodes C60s are general civil engineering/construction industries. The companies in C60s are relatively large and organize engineering/construction project using subcontractors in industries C50s and C70s. It is estimated that the default events occurred in industry C60s triggered defaults of subcontractors in industry C59, C76 and C77. Nodes numbered Wxx represent companies that belong to wholesale industries. Among them, W11 (wholesaler of construction materials), W08 (machinery wholesaler, that includes engineering/constructing machinery) are linked to nodes C50s, C60s and C70s. Thus, it is also estimated that default events in C50s, C60s and C70s triggered defaults of engineering/construction related goods wholesalers in industry W11 and W08.

There seems to be other relations centered by node G05 (golf course) and node W03 (textile goods wholesaler). Many of the defaulted golf courses seem to have had liabilities for drainage works for their course, and for golf carts and course maintenance machineries. The economic background for links G05-C77 and G05-W08 seem to be reasonable.

But the economic backgrounds for links around nodes W03 need further consideration. And other links related to nodes other than construction related industries are not clearly observed. Thus, I examined the data in two parts to get better observation.

(2)Analysis in two parts - Civil engineering/construction related industries and others

The whole data is divided in two groups. One group consists of default events series that start from companies in civil engineering/construction related industries and the other group consists of that start from companies in remaining industries.

(2)-1.Civil engineering/construction related series (Figure 2)

The result of the key graph analysis of this series is about the same as that of whole data. The reason might be that the number and impact of default events in civil engineering/construction industries is so large that the structure of relations among these industries characterizes the structure of relations among the whole industries.

(2)-2.Remaining series (Figure 3)

In addition to the screening of default events series, default events occurred in engineering/construction related industries - industry number C50s, C60s, C70s, N44, N96, W08, W11 - were excluded from each data series in order to decrease the influence of structure of relations among these industries. With this additional screening, the result gets better image although there still remains links to be interpreted with industrial knowledge.

Center of Figure 3 is the island of black nodes. Among the nodes, node W03 (textile goods wholesaler) has largest links all from consumer related retailing/service industries. The link from R43(women's/kids' clothes retailer) is straightforward. The links to R61(restaurants), H51(hotels) and G05(golf course) are expected to indicate sales from W03 to those industries of those goods as textile goods used for service - table cloth, napkin, bedclothes, bathrobe, towel -, uniforms for service persons and cloths to be sold at in-house shop of hotel/golf-course.

H51 and G05 have many links other than those with W03. Both have links with R61. Links between R61, H51 and G05 might reflect failure of resort development projects which generally includes hotels and/or golf courses and restaurants in an area. H51 also has links with S69(business services; temporary worker management, security company i.e.) and S79 (professional service; consultants i.e.). G05 also has links with R99(retailers for sporting goods, tobacco, jewelry i.e. - may indicate retail shops in and around golf course) in addition to those with W03 and R61.

With those analyses it is estimated that failures of leisure projects represented by defaults of hotels and golf courses somehow influenced the rise of defaults in restaurants, textile wholesaling industry and business related services industries. Golf course industry also had strong links with engineering/construction related industries as we saw in above. Thus, it is estimated that defaults of golf courses had large impact over defaults in broad range of industries.

7 Conclusion

In this article, I applied chance discovery method to estimate structure of industrial relations that are to transmit chain reaction of bankruptcy. The result of the analysis of 2005 default data was promising. With further accumulation of analyses and improvement of method, a structure estimated by chance discovery method will sufficiently be a base for risk analysis and risk management of a credit portfolio. The areas for further improvements are;

(1) techniques for analysis and visualization of time order(cause and result relations)
(2) measurement of influence over a default probability of an industry/company of a default event to be transmitted trough estimated industrial relations
(3) modeling of estimated industrial relations in network structure for the use for risk analysis and risk management of a credit portfolio

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Note

∗ A present occupation: The Mitsubishi UFJ Factors, Ltd., Business Planning Department.: This is a personal study to the credit risk of the author. Analysis of Mitsubishi UFJ Factors, which the author belongs to, is not mentioned here.

E-Nightingale: Crisis Detection in Nursing Activities

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Summary. In this chapter, we address the importance of nursing risk management and propose computational models that address it. First, we address the importance and necessity of nursing risk management, then review nursing accidents or incidents from the cognitive aspects of human error. Based on cognitive features, we logically model nursing risk management. In fact, we present an abduction-based model. In the abductive model, nursing risk management is discussed from the viewpoint of Chance Discovery, where we can deal with hidden, rare, or new factors that can be regarded as dynamic risk management.

1 Introduction

Because of widespread malpractice in medical care (nursing), many hospitals have been sued and, sometimes, forced to pay huge amounts of money. Therefore, some hospitals insure against malpractice in medical care to protect themselves from bankruptcy. Of course, malpractice in medical care is not only a problem for hospitals but also seriously affects patients. While taking out insurance might protect hospitals from bankruptcy, it cannot save patients' lives. Thus, it is a rather passive measure for preventing malpractice in medical care.

Recently, it has been recognized that medical or nursing risk management is very important both for hospitals and their patients. Medical risk management aims to reduce medical accidents and minimize the costs of medical care, including insurance fees and financial losses. Of course, it can also save patients' lives. For this reason, there exist accident or incident report databases [21], and risk management experts can refer to such databases to generate generalized patterns for frequently occurring accidents or incidents.

To reduce nursing accidents, it is necessary to collect examples of them. If we collect nursing accidents for analysis, it is possible to detect certain tendencies of nursing accidents and the causality between the environment and

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accidents. Risk management experts then check all of the gathered reports to find the direction of nursing risk management. Since the number of reports is quite large, a computational approach has recently been proposed to analyze the huge number of nursing accident or incident reports [10, 16, 19]. For instance, Park et al. analyzed reports from electronic medical recording systems and generated decision trees from the reports by using ICONS-Miner. Though the reports contain free descriptions, they seem to use only items in the selective-input sections or fixed-input sections. As a result, their result seems to be rather simplistic and trivial, because the selective-input and fixed-input sections only include predictable information. Nevertheless, this approach could be considered a first step toward computerization of nursing report analysis. Although their proposal is quite simple, in future we will be able to extend the method to analyze more complex relationships.

Thus, by conventional data mining techniques, common phenomena and frequently occurring accidents can be found. For conventional risk management, analysis of common phenomena and frequently occurring accidents would be satisfactory to protect against typical nursing accidents or incidents. A set of collected examples works as a textbook for protection against nursing accidents. Accordingly, this type of risk management becomes a type of static risk management. However, for special cases or cases we of which cannot be aware, another type of data mining technique is required. This is because a special case can be regarded as a sort of noise to a conventional data mining system, and such cases are usually ignored during data mining procedures. In addition, it is quite difficult to assess the events that are easy to ignore but difficult to recognize. Sometimes, an ignored event can be a significant factor in a rare or novel accident. Since there may be a hidden relationship between an ignored event or factor and an accident, it is necessary to prepare a technique that can discover such hidden relationships. Thus, it is more important to deal with ignored, rare, or novel factors than frequently observed ones. Chance Discovery is a research field dealing with such rare or novel factors. In contrast with the static risk management mentioned above, we can conduct dynamic risk management that can handle unknown or lesser known risks.

In this chapter, we give an overview of and model nursing risk management in the E-Nightingale project. First, we address the importance and necessity of nursing risk management, then review nursing accidents or incidents from the cognitive aspects of human errors. Based on cognitive features, we logically model nursing risk management, and actually show an abduction-based model. In the abductive model, nursing risk management is discussed from the viewpoint of Chance Discovery, where we can deal with hidden, rare, or new factors that can be regarded as dynamic risk management. Section 2 illustrates nursing risk management, then Section 3 introduces the E-Nightingale Project. Section 4 reviews human error from a cognitive aspects, and Section 5 characterizes nursing risk management as Chance Discovery. Section 6 then proposes an abductive procedure to conduct nursing risk management in the context of Chance Discovery.

2 Medical and nursing risk management

Despite recent high-quality nursing education and advanced medical treatments, the number of medical accidents due to nursing activities has not decreased. Rather, expectations about the safety and quality of nursing care have increased, and the range of nursing responsibilities has expanded. Therefore, to reduce the occurrence of medical accidents, it is important to reduce nursing accidents and incidents to benefit both hospitals and patients.

Accordingly, some hospitals have introduced a medical risk management section to analyze medical accidents, including nursing accidents, and one frequently used method of doing so is analyzing nursing accident or incident reports. Recently, a computational approach was proposed to analyze the huge number of nursing accident or incident reports, for instance, [10] and [16], but such analysis is still mainly done by human risk management experts. Analyzing nursing accident or incident reports is vital for reducing the same or similar accidents or incidents in the future. In addition, analyzed data have been published such as a database of accidents or incidents reports [21] to share acquired knowledge.

In actual practice, many factors, such as environment, might cause nursing accidents or incidents. However, in this chapter, we only give an overview of nursing risk management from the viewpoint of human error. Though we should consider environmental and system-dependent factors, since some of these are inherently involved in human-related factors, in this chapter we only deal with explicitly human-related factors. In addition, most nursing accidents or incidents are caused by confusion about procedures or patients during transfusions or injections or the mis-operation of medical equipment, among other possibilities. Most nursing accidents or incidents are caused by simple and rudimentary mistakes in everyday tasks. Accordingly, as a first step, we must focus on explicitly human-related factors.

As shown in the Introduction, we contrast static risk management and dynamic risk management. Conventionally, static risk management is conducted, because if we collect many examples, we can build a textbook on frequently occurring risks. This type of risk management is regarded as static risk management which is powerful for common cases, but it cannot handle rare or novel situations. As we will explain, for actual situations it is more meaningful to handle rare or novel cases. Therefore, we focus on the human error aspects and rare or novel cases to model nursing risk management that can be regarded as dynamic risk management.

3 E-Nightingale Project

For effective nursing risk management, it is necessary to obtain data that includes both explicit and implicit (hidden) information that has a certain relationship with the environment. It is quite difficult for individuals to read all environmental factors from accident or incident reports, because not all environmental information can be included in them. Consequently, in addition to accident or incident reports, an automatic environment-monitoring system will be needed to obtain the full range of environmental factors.

It has been pointed out that one of the major causes of disasters in manufacturing plants is the fact that people working in job sites lack enough knowledge and experience. To solve this problem, we need the technology to capture experts' everyday activities along with their surrounding situations, to understand these activities and situations, to transform this understanding into a form of knowledge that can be utilized effectively even by novices, and finally to provide this knowledge to the people who need it. In response to these needs, we proposed the E-Nightingale project to solve such problems [6]. The aim of the project was to establish the fundamental technologies of a system for knowledge-sharing based on understanding everyday activities along with their surrounding situations. The technology described above should improve everyday activities not only in manufacturing but also in such fields as medical services, elderly care, emergency services, firefighting, and policing, all of which require expertise. Among these fields, this project focuses on medical services because of their importance and the urgent need for such technology. The project has chosen nurses in medical institutions as intended users because they most often experience medical accidents and incidents.

Our intention with this project is to develop the following three systems:

- A nursing duty record and analysis system;
- A just-in-time nursing advice system; and
- An accident/incident video documentation system.

Figure 1 shows the concept of the E-nightingale project.

In the project, Kuwahara et al. proposed an integrated nursing activities monitoring system that couples ubiquitous apparatus with fixed apparatus

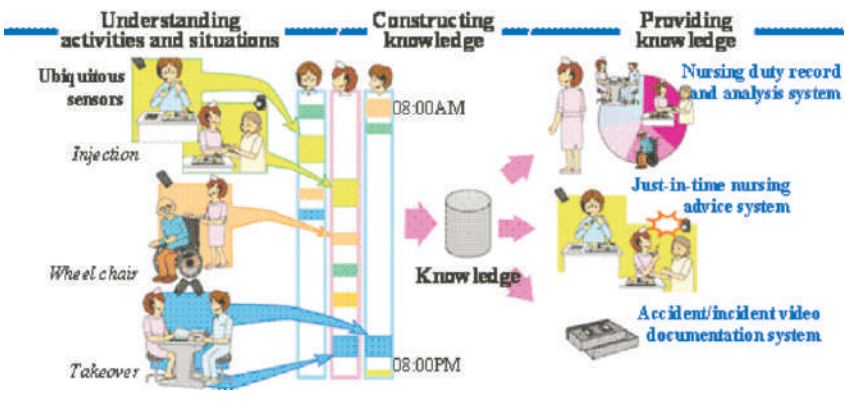

Fig. 1. Concept of the E-nightingale project.

[7, 8]. This system was proposed to monitor work-flows of nurses' activities to report their entire work-flows in real time on their behalf. When a nursing error occurred, the monitored data could be used to determine its root cause.

In the current (experimental) system, nurses carry wearable sensors that record their conversations, dialogues, footstep numbers, and body angle etc. In addition, cameras are placed in each room to record part of their activities visually (no sound), while radio-frequency (RF) stations are installed to record nurses' location. Figure 2 shows wearable sensors. The left figure shows sensors including a digital recorder for the pocket.

By using the system, nurses' activities (workflows) are automatically monitored and recorded, allowing various types of data on nursing activities to be obtained. For instance, from footstep numbers and body angles, we can intuitively guess their working category such as caring at the bedside, helping to move patients, and making documents etc. In fact, Naya et al. [9] illustrated the possibilities of automatically classifying nursing practices. In addition, if we use a video monitoring system, we can confirm their working category and discover what nurses themselves were not aware of.

Abe and Ozaku built dialogue corpora for both nursing activity analysis and for constructing nursing ontologies [4, 13, 14, 15]. From these corpora, a knowledge base for nursing activity models can be organized, making it possible to create nursing accident or incident models. Therefore, we are currently collecting various types of voice data in various departments of hospitals by using the above ubiquitous apparatus.

Details of monitoring systems and analysis of nursing activities were and will be discussed in [8] and other papers. In this chapter, we focus on determining nursing accidents or incidents and producing an effective alert strategy to nurses to avoiding nursing accidents or incidents from the viewpoint of Chance Discovery. Techniques and concepts discussed in this chapter can be applied to the just-in-time nursing advice system in Fig. 1.

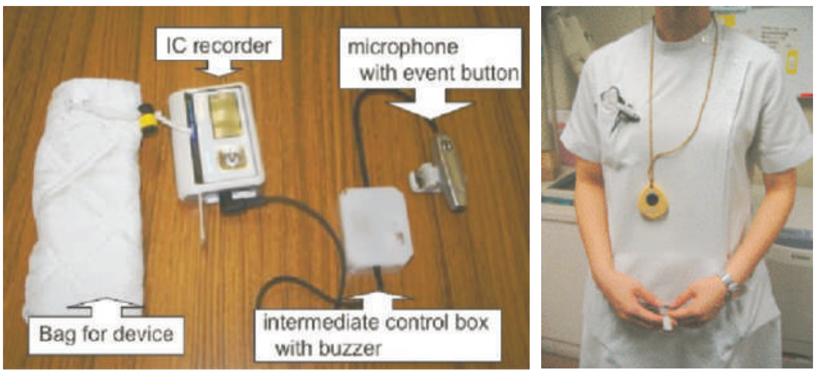

Fig. 2. Wearable sensors.

4 Human errors

In Section 2, we pointed out that it would be satisfactory to focus on explicitly human-related factors. In this section, we overview human errors from the cognitive or psychological viewpoint.

Vincent divided human errors into two types [20]:

- Mistakes
  A mistake is a consciously deliberate incorrect action based on an incorrect decision. As an example of a mistake is that every hospital has its own system, but staff from other hospitals tend to be **convinced** that the previous rules still apply and thus act incorrectly regardless of the new hospital's rules.
- Slips
  Slips are inadvertent and unintentional actions that cause an inappropriate reaction from the system. An example of a slip is the following incident: "Since the nuclear medicine inspection had been cancelled many times, only distilled water had been drawn into the injector for preparation. I planned to dissolve the Diamox just before the injection, so I placed it beside the injector. Since I was convinced that I had already dissolved the Diamox, I passed the injector filled only with distilled water." A keyword for a slip is "discontinuation." Discontinuation of a task tends to lead it in the wrong direction. In this case, context shift [12] does not occur, but due to discontinuation, the personal context seems to change. Consequently, people tend to go in the wrong direction or forget to perform a necessary intermediate process.

Although the keyword **convince** only appears in the definition of "mistake," in accident or incident reports the word **convince** appears in both cases. Accordingly, a **convinced** situation is one of significant factors in causing an accident or incident. Thus, solving problems in nursing risk management should analyze the feature and process of convinced situations.

4.1 Convinced situation

While reviewing accident or incident reports, we frequently noticed the word "convinced" and detected a common feeling that can be designated as "convinced." Most accidents or incidents seem to be caused by a "convinced" situation or a careless situation. Of course, simple accidents are caused by carelessness, which is a major factor in most accidents. For nursing risk management, an accident based on carelessness is easy to deal with because carelessness can be observed from the outside. However, a convinced situation is more difficult to observe from the outside because it is an invisible psychological condition. Therefore, to prevent accidents or incidents, it is important to analyze the psychological process that produced such a feeling of being convinced. As shown above, the convinced situation seems to be caused by a

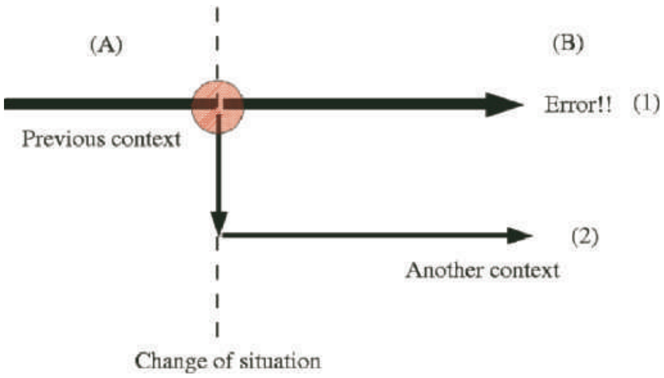

Fig. 3. Process of a mistake.

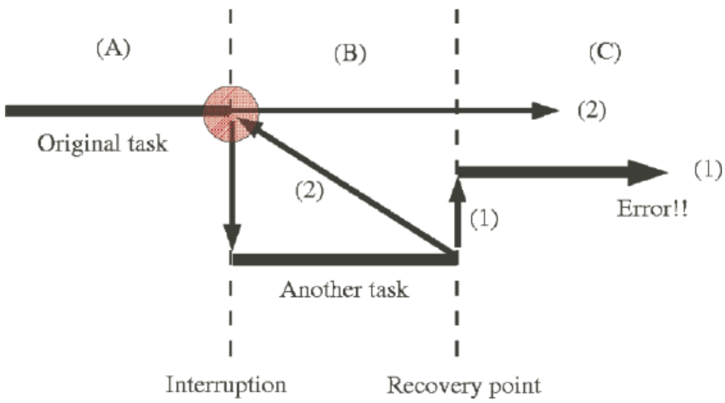

Fig. 4. Process of a slip.

certain shift of context. In the case of a mistake, since a staff has his/her own context and never changes it, he/she cannot act correctly when the context changes (Fig. 3). In this case, following individual context causes errors. For example, changing one's working location from the fourth floor to the ICU may cause an accident or incident because the working style is quite different between the two places. If the nurse persists in the previous working style, he/she will make errors. This is the case in the above situation. Also, when the nurse must use new equipment, the same situation will occur. In this case, risk managers must educate staff in differences or new procedures to prevent possible errors. Mistakes can be overcome by proper education.

In the case of a slip due to (unintentional) discontinuation of a task, a staff cannot maintain context (Fig. 4). For example, during the nuclear medicine inspection, he/she waited for the next step without completing one task (dissolving the Diamox); after performing another task, his/her context moved to the ideal context, which is the completed task, instead of going to the actual context. The confused context caused an accident. In this case, the difficulty of maintaining one's own context caused an error. When nurses are busy, the same situation frequently occurs. Also, if the system is quite complicated or the place of work is not clear, the same situation — discontinuation — occurs and causes human errors. However, even when the nurse is not so busy, the same situation sometimes occurs, being too busy and working with complicated systems are not the only reasons for slips. One problem is that we humans are easily convinced that an ideal situation exists, which is a matter of human nature. Another problem is that people are not conscious of their wrongly convinced situations.

Thus, one way to prevent nursing accidents or incidents is to predict or detect the (unconsciously) wrongly convinced situation and remove it. In the following section, we propose a method to protect against nursing accidents or incidents from the viewpoint of Chance Discovery by focusing on a rather rare type of incident or accident.

5 Nursing risk management as Chance Discovery

5.1 What is a chance in nursing risk management?

Chance Discovery [11] is a framework that deals with rare or novel situations. It is a framework that discovers and suggests symptoms that may cause serious situations (good or bad) in the future. Such symptoms are called "chances," and in an intuitive sense, a chance can be regarded as unknown reasons or factors for an opportunity or a risk. In fact, in [11], "chance" is defined as follows:

> A chance (risk) is "*a new or novel event/situation that can be conceived either as an opportunity or a risk.*" It is naturally understood that a chance, which is either known or unknown, includes the possibility of eliciting unfamiliar observations.

In the previous section, we discussed removal of *unconsciously* convinced situations as protection against nursing accidents. Thus, risk management itself can be thought of as an application of Chance Discovery. A *chance* in nursing risk management can be defined as an "ignored" event, factor, environment, personal relationship or personal matter that has the possibility to cause a serious nursing accident or incident in the future.

5.2 Nursing risk prediction as Chance Discovery

In an accident or incident report, an accident is defined as accidental damage. In contrast, an incident is defined as an event that may become an accident.

That is, an accident seriously affects patients, whereas an incident is an event that has not seriously affected patients but has an opportunity or a risk (= chance) to cause serious problems under another condition. Although an incident does not in itself seriously affect on patients, we must be careful of both accidents and incidents.

It is important to predict accidents and incidents to protect patients from serious risks to their health. One method of predicting accidents or incidents is the so-called data mining technique. If we analyze a set of accident and incident examples, we can generate general rules for accidents and incidents. If we refer to the rules, we can predict the possibility of common accidents and incidents. Thus, with these rules, it is possible to prevent most accidents and incidents. However, only static risk management can be achieved. From the viewpoint of Chance Discovery, it is more important to make the users (nurses or doctors) aware of any possible hidden (ignored or unconscious) event, factor, environment, personal relationship or personal matter that may cause an unrecognized but serious accident in the future. That is dynamic risk management. As explained above, hospitals usually have a system for analyzing accident or incident reports to generate case examples (textbooks) of medical (nursing) them. Computational methods are frequently applied to analyze accident or incident reports. Currently, however, computers can only generate rules that explain well known accidents or incidents; in fact, most of the cases handled are trivial or common accidents. The result is not fully adequate because we cannot determine any chance from it. It is therefore necessary to provide a method that can dynamically detect hidden factors that have a relationship to future accidents. For dynamic nursing risk management, techniques achieving Chance Discovery are required.

5.3 Chance Discovery in nursing activities

From the viewpoint of Chance Discovery, a rare or novel event is a key event to a risk (error). We can analyze two types of human error from the viewpoint of Chance Discovery. As for a mistake, in [2] and [3], we analyzed the hypothesis that a mistake is caused by the impossibility of following a "context shift" or lack of awareness of a shift in context. Thus, when a new situation is rare or novel, we make mistakes. In contrast, for a slip, we analyzed the hypothesis that due to (unintentional) discontinuation, the situation becomes rare or novel. In both cases, rare or novel situations cause accidents or incidents.

Thus, in the case of a mistake, a change of environment (for example, the working location is changed from the fourth floor to the ICU) may cause an accident or incident. This case is easy to understand. To avoid accidents or incidents, those who change their environment should be mindful of the difference. In this case, awareness of the difference is important to prevent accidents or incidents. Similar to the slip case, this one can be regarded as a discontinuation of environment. Thus, a chance exists at the hatched circle in Fig. 3.

In the case of a slip, a stimulus such as (unintentional) discontinuation or interruption changes the environment and may cause an accident or incident. If a discontinuation or interruption occurs, we recall a previous situation. However, in some cases, our memories seem to jump to an ideal or desired situation while performing a task in another reality. Consequently, accidents and incidents frequently occur. Due to unexpected events, although an ideal or desired situation has not actually been achieved, we *unconsciously* convince ourselves that we have achieved such an ideal or desired situation. Thus, a chance exists at the hatched circle in Fig. 4. In this case, awareness of the previous situation is important to prevent accidents and incidents. Thus, risk-alarm systems should properly alert the users to remind them of previous situations or the current one. As explained earlier, the problem is how to detect an unconsciously convinced situation. This is a key to dynamic risk management. The most significant matter is warning the users at the exact point where an accident or incident is likely to occur. If we are warned even when we are properly conducting our jobs, we finally tend to ignore all the warnings even if they are actual ones. In this case, a warning becomes meaningless and harmful.

6 Chance determination in nursing risk management

In the previous section, we pointed out the importance of dealing with possibly hidden (ignored or unconscious) events, factors, environmental elements, personal relationships, or matters likely to cause an unrecognized but serious accident in the future. Such factors can be regarded as chances. In this section, we model risk management based on abduction.

6.1 Abduction model

In [1], we pointed out that abduction appeared to be a useful framework for performing Chance Discovery. As shown below, abductive reasoning can be applied to the discovery of a critical point and the explanation of consistency in a nursing procedure. Thus, abduction seems to be a promising framework for detecting the critical point in a nursing accident. Of course, since abduction can be directly applied to the analysis of nursing activities, in [2] we formalized nursing risk management with an abductive framework. In cases where we know all possible hypotheses and their ideal observations[1], we can detect malpractice beforehand because if someone selects an incorrect hypothesis set or fails to generate a necessary one, an ideal observation cannot be explained. When an ideal observation cannot be explained, an accident or incident will occur. By this mechanism, we can logically determine where

[1] If we use a workflow sheet for nurses or an electronic medical recording system, we can determine ideal observations.

accidents or incidents are likely to occur before they do. A simple logical framework to complete an activity is shown below (by using the framework of Theorist [17]):
If

$$F \cup h_1 \not\models ideal\_observation, \tag{1}$$

then find h_2 satisfying (2) and (3) from H.

$$F \cup h_2 \models ideal\_observation \tag{2}$$

$$F \cup h_2 \not\models \Box. \tag{3}$$

$$h_1, h_2 \in H. \tag{4}$$

Here F is a set of facts that are always consistent, and h_1 and h_2 are hypotheses that are not always consistent with the set of facts and other hypothesis sets. Hypotheses are generated (selected) from hypothesis base H. $\Box$ is an empty set. Therefore, the last formula means that F and h_2 are consistent.

If we can complete formula (2), the activity is successfully completed. On the other hand, if we cannot generate enough hypothesis sets to complete formula (2), certain problems will disturb the completion of the activity. Thus, beforehand we can determine the possibility of risk by abduction. That is, when we cannot explain an *ideal_observation* with a current hypothesis set, a certain error might occur. If objective (*ideal_observation*) cannot be explained, it cannot be completed. This situation is caused by certain accidents or incidents.

6.2 Risk management procedure

In the section above, we presented a dynamic risk management model based on abduction. In this section, we illustrate a risk management procedure with the following simple example from [21].

> Since the nuclear medicine inspection had been cancelled many times, only distilled water had been drawn into the injector for preparation. I planned to dissolve the Diamox just before the injection, so I placed it beside the injector. Since I was convinced that I had already dissolved the Diamox, I passed the injector filled only with distilled water.

Let part of the knowledge base be as follows:

- fact set (F)
  $injection(X)$:- $content(X) \wedge distilled\_water \wedge give\_injection.$
  .....
- hypothesis base (H)
  $content(X).$
  $give\_injection.$
  $give\_inspection.$

$give\_DIV.$
....
$distilled\_water.$
$Diamox.$
$Minomycin.$
....

We assume that by using sensor monitors such as cameras and RFID tags, some hypotheses such as $give\_injection$ and $distilled\_water$ can be observed. This is a realistic assumption. Since we are researching this type of monitoring system in the "E-nightingale project" [8], with the help of an electronic medical recording system, the above observation can indeed be achieved.

The aim of the nursing risk management system in this case is to lead the user to complete an injection of Diamox ($injection(Diamox)$) after a certain unintentional discontinuation of a task. Therefore, the aim is in fact to explain an $ideal\_observation$, which here is $injection(Diamox)$ after the unintentional discontinuation of a task. An explanation for $injection(Diamox)$ can be achieved by hypothetical reasoning as follows:

$$F \cup h_1 \not\models injection(Diamox). \tag{5}$$

$$h_1 = distilled\_water \cup give\_injection. \tag{6}$$

In conventional hypothetical reasoning, h_1 is generated (selected) from H, but in this framework, it is generated by reflecting on the actual situation. In this case, $injection(Diamox)$ cannot only be explained by h_1. When $injection(Diamox)$ cannot be explained, h_2 is generated from H by a hypothetical reasoning procedure. Consequently, $Diamox$ is adopted as a necessary hypothesis to explain $ideal\_observation$, and the following explanation can be achieved:

$$F \cup h_2 \models injection(Diamox). \tag{7}$$

$$h_2 = Diamox \vee h_1. \tag{8}$$

The nursing management system should warn the user that "Without Diamox, an accident might occur!" Of course, if the user uses incorrect medicine, as shown in the following, the explanation cannot be completed and the nursing management system should warn the user that, "Something is wrong, so an accident might occur!" The user will then check the medicine to ensure the current one is being used.

$$h_2' = incorrect\_medicine \vee h_1. \tag{9}$$

$$F \cup h_2' \not\models injection(Diamox). \tag{10}$$

On the contrary, from the first step, if the following explanation is completed, the system does not need to warn the user.

$$F \cup h_1' \models injection(Diamox). \tag{11}$$

$$h'_1 = distilled\_water \vee Diamox \vee give\_injection. \quad (12)$$

If H does not include $Diamox$, the risk management system can warn that, "Something is missing, so an accident might occur!" However, even in such a situation, if we apply CMS [18], which can be regarded as abduction, and suggest a missing hypothesis set as a negation of minimal support, sometimes the system can suggest a missing hypothesis as $Diamox$ and warn the user.

Thus using abduction enables us to build a nursing-error alarm system that forms part of the nursing risk management system within E-Nightingale, which can properly warn users. Although the above example is quite simple, abductive reasoning can be applied to the discovery of critical points and the explanation of consistencies in nursing procedures. Thus, abduction seems a promising framework for detecting the critical point in a nursing accident. Of course, abduction can also be directly applied to the analysis of nursing activities.

This abduction model is a very simple logical model that does not consider any effects of the order of generating hypotheses. The abduction model considering time information is discussed in [5].

7 Conclusions

In this chapter, we addressed the importance of nursing risk management and proposed an abduction-based model that addresses it. This is part of the E-Nightingale project, the aim of which is to support knowledge sharing for everyday activities [6]. In fact, we have a plan to apply the abduction-based dynamic nursing risk management model to the just-in-time nursing advice system. For dynamic risk management, the concept of Chance Discovery was introduced. In this chapter, we contrasted a static model with a dynamic model. We believe dynamism is very important in risk management. For instance, if we had been able to predict the end of the economic bubble phenomenon in Japan, the current economic situation in Japan might have been different: Relative economic stagnation might have not occurred. This type of rare or novel situation cannot be explained by stochastic models such as the Black-Scholes model, where only a few clever people win the game. For risk management, a static model is of course useful, but we must reconsider the model to deal with unknown or lesser known situations. At the end of the chapter, we address that "dynamism" as the most important factor in risk management. This dynamism can be achieved using Chance Discovery powered by abduction.

Acknowledgments

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Understanding of Dark Events for Harnessing Risk

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Summary. There are invisible events which play an important role in the dynamics of visible events. Such an event is named a *dark event*. Understanding of the dark event is important for *harnessing risk in modern social and business problems*. A new technique has been deveoped to understand dark events and to extend the chance discovery process. The technique is *human-interactive annealing* for revealing latent structures along with the algorithm for discovering dark events. Test data generated from a scale-free network shows that the precision of the algorithm is up to 90%. An experiment on discovering an invisible leader hidden under an on-line decision-making circumstance and a trial for the analysis on unknown emerging technology are demonstrated.

1 Introduction

A chance means an event with significant impact on human's decision-making [16]. It could be conceived either as opportunity or as risk [18]. The chance discovery process is designed for noticing a sign suggested by observed events and for putting new and significant scenarios into concrete shape [17]. In the process, a software tool named KeyGraph interfaces computational data processing, with human recognition and intuition. KeyGraph analyzes co-occurrence between observed events. It produces an event map and indicates a chance as a visual structure. The structure is a weak relationship bridging between multiple event clusters [5]. In these features, the chance discovery is different from rare events or exception rules in data mining [20], [22], and knowledge creation process [9].

Experts of the chance discovery process, however, began to recognize a new problem, where the ordinary KeyGraph fail to visualize a latent structure hidden behind observation. It has been noticed empirically that important events composing the latent structure are neither visible nor observed in many

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social and business problems. Such invisible events are particularly important for harnessing risk. Let us describe two examples.

In human network analysis, it has drawn much attention to analyze terrorist organizations and to capture the signs of attacks. It is important to acquire information on leaders, close associates, important persons, and a chain of command to the individual terrorists. The terrorist organizations hide such information in the visible data like communication logs, telephone records or emails. The leader seems to penetrate the organization like an invisible atmosphere and to synchronize individual terrorists toward the attack objective. This invisible atmosphere is a latent structure behind observed terrorist organization activities. Essentially, governments, intelligence offices, and secret services need understanding of the latent structure and an insight into a scenario for harnessing and removing risk from invisible terrorism.

In technology research and development, strategies on intellectual properties are critical to earning, costing, and even survival of companies. It is important to detect if competitor companies possess undisclosed surpassing technologies and expertise. Decision-making on making, buying, or licensing technologies is subject to such competitor companies' properties. Particularly, a sub-marine patent had been a great threat. Its publication is intentionally delayed by the applicant so that its presence and application can not be made visible. Such invisible technology is a latent structure behind complementarities and substitutability relationship among technologies and their holder companies. Essentially, strategists for corporate research and development need understanding of the latent structure and an insight into a scenario for harnessing and removing risk from hidden technologies.

From these examples, it is learned that there are invisible events which play an important role in the dynamics of visible events. Such invisible events are named dark events after dark matter in cosmology. New and significant scenarios for harnessing risk shall be put into concrete shape by understanding presence, nature, interaction and meaning of the dark events. But invisible dark events have not been within the scope of the chance discovery process. We have developed a new technique; *humna-interactive annealing* of latent structures along with crystallization algorithm of dark events to understand dark events. After studying the basic features of dark events, the principle of the technique and two application examples for harnessing risk in the real world are presented in the following sections.

2 Dark event

A new idea; *dark event* is introduced to formulate the problem described in section 1. The dark events are neither visible nor observable. Their associations to visible events form a latent structure hidden behind observation. But, the dark events are essential in the dynamics which governs temporal and spatial behavior, structure forming and life cycle of visible events. The dark event is analogous to dark matter in cosmology. The dark matter refers to hypothetical particles which do not emit or reflect radiation to be detected directly. But its presence can be inferred from gravitational effects on visible matter such as stars and galaxies. The dark matter hypothesis aims to explain several anomalous astronomical observations in the stellar dynamics. Estimates of the amount of the dark matter suggest that there is far more matter than is directly observable. If dark matter does exist, it vastly outmasses the visible part of the universe. Before studying a means to analyze dark events closely, classification of events into four classes are presented. They are dark event, chance, visible event and event cluster. The chance, visible event and event cluster have been within the scope of the chance discovery process with KeyGraph.

- *Dark event*: The first class is dark event. The dark event is invisible because its occurrence frequency is very small. The dark event is diffusing randomly like an atmosphere because its association with other events is very weak. It does not tend to cling to a particular event cluster. It does not tend to appear as a pair with a particular event. In consequence, its co-occurrence is very small. This class of events has not been within the scope of chance discovery.

- *Chance*: The second class is chance. It is an infrequent but important event. Its occurrence frequency is very small. But its co-occurrence with a particular event or event cluster is not very small. KeyGraph are equipped with algorithms to analyze co-occurrence with Jaccard coefficient or Dependence coefficient. This class has been a major focus of chance discovery. KeyGraph visualize chance as a red node bridging between black node islands representing event clusters on an event map.

- *Visible event*: The third class is visible event. It is a frequent event. Its occurrence frequency is large. It can be observed easily. But its co-occurrence with a particular event or event cluster is not large. KeyGraph visualize a visible event as an isolated black node. So far the visible event has not been given large significance in chance discovery.

- *Event cluster*: The fourth class is event cluster. It is a set of frequent and strongly related events. Its occurrence frequency is large. Its co-occurrence with a particular event or event cluster is large as well. KeyGraph visualize an event cluster as a big black node island including many inter-connected black nodes. The event cluster is important as a reference point of observation to discover chance as a bridge node connected to it. The event clusters have a regular, ordered and stable nature.

The following is a working hypothesis on dark events and the evolution of chance. The dark events which are about to change into a chance may look like an emerging order in a chaotic structure. The chaotic structure close to the order may be discovered by identifying dense dark events and by analyzing them. On the contrary to the ordinary chance discovery process, human-interactive annealing of latent structures along with crystallization algorithm of dark events addresses the problem to understand dark events. Their details are described in the following sections.

- Hypothesis 1: Risk (or opportunity) shall originate in dense dark events, grows into a visible event (cluster), and matures into a well-understood scenario.

3 Annealing of latent structures

Before detailing the human-interactive annealing process, a little space is spent to learn a general meaning of *annealing*. Annealing in materials science is a heat treatment where the structure of a material is altered. It causes changes in the physical property such as strength through removal of crystal defects and the internal stresses. The annealing heats up a material piece until its temperature reaches a stress-relief point and cools down the piece slowly. Similarly, simulated annealing [4] is a probabilistic technique of computational optimization based on physical formulas describing the annealing in materials science. It is used to discover the optimal point in a large search space.

The human-interactive annealing similarly seeks the optimal point. It should be noted that the optimal point is in terms of human's creativity for new and significant scenarios. The annealing visualizes human recognition of the observed data into an event map. The optimal event map activates human's creativity most strongly. Our technique is based on the following working hypothesis on human recognition and creativity. The optimal event map is neither in ordered structure nor in chaotic random structure. The ordered structure is a group of well-understood concepts in human recognition. Mixing it with chaotic nature of dark events results in strong activation of human's creativity for new and significant scenarios. Such a structure is maintained in the basin of chaos between order and chaos [10].

- Hypothesis 2: Mixing the ordered structure of well-understood concepts with chaotic nature of dark events shall result in strong activation of human's creativity.

The human-interactive annealing process is a combination of two complementary elements; crystallization algorithm on computers and human's interpretation. The two elements are illustrated in figure 1 with five event map examples. In the event maps, the event clusters and dark events are drawn schematically. The dark events are made visible, owing to the crystallization algorithm. The horizontal axis is the number of iteration. The vertical axis corresponds to the randomness of the visualized event structure. A parameter to control the randomness (like temperature) needs be introduced. It could be

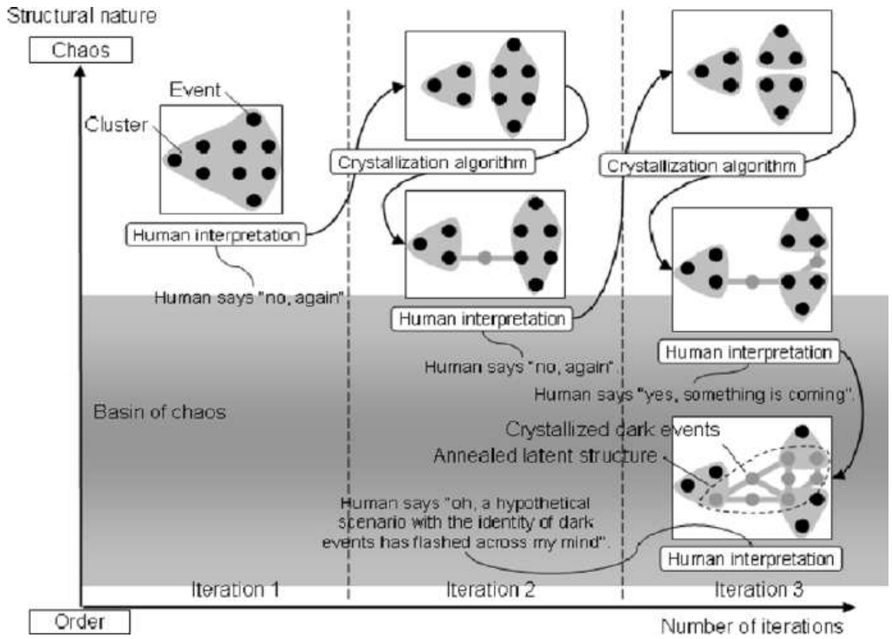

Fig. 1. Human-interactive annealing process for levealing a latent structure. The horizontal axis is the number of iteration. The vertical axis corresponds to the randomness of the visualized event structure.

the number of event clusters or the total number of edges between events. The iteration is continued until human converges into complete understanding.

Crystallization algorithm is a breaking-through method by Ohsawa [15], where dummy events which may potentially corresponds to the dark events are visualized. Yet, the complex algorithm and the complex graph obtained were hard to understand for users. It has been desired that user can reflect the user's interest in the visualization for focusing the obtained graph to understandable simplicity. We have modified the algorithm and incorporated it into the annealing process. In the crystallization, the computer analyzes the occurrence frequency and the co-occurrence of events. In the heating step, up to the specified peak temperature, the number of clusters and edges between visible events decrease. Weak associations are destroyed. The crystallized dark events disappear. Then, a cooling step comes after the heating step, where event structures are solidified as temperature goes down. The number of crystallized dark events between clusters of visible events increases on an event map. The clusters are connected to each other to form a single large structure. The crystallization is followed by human's interpretation, where it is also checked whether the termination condition is fulfilled.

In the human's interpretation, let us assume that the process involves a group of humans, as in the previous cases of chance discovery. The humans put annotation to individual structures appeared on an event map, guess the meaning of dark events, and put scenarios into a concrete shape. If the structure does not match their intuitive recognition, they start annealing iteration again. It is a trigger of a heating step where event structures are dissolved as the temperature goes up to the next peak temperature. The peak temperature is specified based on the degree of understanding. When the understanding is poor, they should not change the peak temperature largely, but should stare at the current graph on an event map. On the other hand, if the structure matches their intuitive recognition approximately, they can re-start crystallization algorithm again to crystallize dark events further. If the structure implies novel scenarios of event occurrence finally, the iteration terminates, ending in complete understanding.

4 Crystallization algorithm

A new simplified crystallization algorithm has been developed to visualize dark events. This section details the algorithm, implementation with KeyGraph, and evaluation with measures of precision and recall. The basic idea of the crystallization algorithm is that visible dummy events are inserted to the input observation data to represent dark events. A dummy event is a symbolic expression of a latent structure containing dark events.

4.1 Crystallization of dark events

Observation data from which occurrence of events and co-occurrence between them can be evaluated shall be the input. For simplicity, we take basket data as an example of the input data format. The content of the basket is a set of events grouped under a specific subject. They may be a group of events observed simultaneously, or a group of events having some properties in common. Another typical input data format is vector representation of events in the multi-dimensional observation space. Before processing the baskets with the crystallization algorithm, the number of clusters, $|C|$ must be specified. At the first iteration, $|C|$ is initialized to be unity or a small number. After that, $|C|$ is gradually increased, based on the human interpretation. A generic crystallization algorithm under a specified number of clusters consists of five steps, event identification, clustering, dummy event insertion, co-occurrence calculation and topology analysis.

1. *Event identification*: The all events appearing in the baskets $B = \{b_i\}$ $(i \in [0, |B| - 1])$ are picked up. The event set is denoted by E. The individual item is denoted by e_i $(i \in [0, |E| - 1])$.

2. *Clustering*: The event set E is classified into groups under a specified number of groups. This step can employ many existing technical expertise in statistics and machine learning such as clustering [7], [4], unsupervised learning [14], projection of high dimensional data [1], visualization [8], and latent variable analysis [3]. Clustering consists of partitioning a data set into subsets, so that the data in each subset share some similarity or proximity for some defined distance measure. Unsupervised learning is a method of machine learning where a model is fit to observations as input. It is distinguished from supervised learning by the fact that there is not a priori output to be learned or inferred from teacher data. The cluster set is denoted by C. The individual cluster is denoted by $c_i (i \in [0, |C|-1])$.

   Existing clustering algorithms can be employed. Clustering may be hierarchical or non-hierarchical. The hierarchical clustering may be either divisive or agglomerative. The non-hierarchical clustering may use k-means algorithm, k-medoids algorithm, or equivalents. Kohonen's self-organization map (SOM) [11], [7], or graph theory based clustering methods [4] may also be applied. In either algorithm, a measure to evaluate similarity or dissimilarity between a pair of events is necessary. Similarity can be evaluated as co-occurrence of two items within baskets. Jaccard coefficient (equation (1)) and Dependence coefficient (equation (2)) are popular examples [13], [12]. The occurrence frequency of an event, e_i is denoted by $\mathrm{Freq}(e_i)$. They are an estimate of an association measure. The Dependence coefficient is called expected confidence, or lift.

$$\mathrm{Ja}(e_i, e_j) = \frac{\mathrm{Freq}(e_i \cap e_j)}{\mathrm{Freq}(e_i \cup e_j)} \tag{1}$$

$$\mathrm{Dep}(e_i, e_j) = \frac{\mathrm{Freq}(e_i \cap e_j)}{\mathrm{Freq}(e_i) \times \mathrm{Freq}(e_j)} \tag{2}$$

   Finally, calculated clusters c_i $(i \in [0, |C|-1])$ are drawn on an event map. Links are drawn between a pair of events having large co-occurrence within individual clusters.

3. *Dummy event insertion*: A dummy event DE_i is inserted into a basket b_i [15]. If $\{e_i\} \in b_i \equiv \{e_j\} \in b_j$ for $i \neq j$, DE_j is set to DE_i. The basket becomes $b_i \rightarrow \{\{e_i\}, \mathrm{DE}_i\}$. The dummy event represents a set of latent participants to the basket. It also corresponds to the subject to the basket. These are the first order dummy events. Higher order dummy events can also be inserted into baskets. For examples, the third order dummy event DE_{ijk} is inserted into baskets b_i, b_j and b_k.

4. *Co-occurrence calculation*: Co-occurrence between a dummy event and clusters is evaluated. In case of Jaccard coefficient, equation (3) is used.

In equation (3), the function, max (maximal) may be replaced by functions, ave (average) or min (minimal), depending on the problem nature.

$$\mathrm{Co}(\mathrm{DE}_i, C) = \sum_{j=0}^{|C|-1} \max_{e_j \in c_j} \mathrm{Ja}(\mathrm{DE}_i, e_j) \tag{3}$$

Two types of dummy events have large value of co-occurrence. One is those having large expected confidence with particular clusters. The other is those having relatively large expected confidence with relatively large number of clusters.

5. *Topology analysis*: The dummy events DE_i are ordered based on the co-occurrence with the clusters. The dummy events having large co-occurrence are picked up. The dummy events are connected to the clusters. The number of links between the dummy events and clusters is limited to 2 to 4 empirically. The number of picked up dummy events is increased until the all clusters are connected. Finally, the dummy events and links to the clusters are drawn on the event map. This structure reveals a latent structure consisting of dark events.

4.2 Implementation with KeyGraph

The crystallization algorithm can be implemented with the existing KeyGraph [18]. KeyGraph employs a force-direct placement technique to draw a graph [6]. The edges are replaced with a spring having characteristics depending on the co-occurrence to form a mechanical system [19]. An edge between vertexes having Jaccard coefficient above a threshold is subject to an attractive force. As a result, they tend to come close together. The vertices move until the mechanical system comes to an equilibrium state. Although the distance on the event map has no strict meaning, closeness between events approximately represents the strength of the relationship.

At first, dummy events are inserted to the original basket data. The first order dummy events are used. Higher order dummy events are neglected because their occurrence frequency ($\mathrm{Freq}(\mathrm{DE}_i) > 1$) results in wrong frequency analysis and clustering in KeyGraph algorithm. Then, KeyGraph output an event map. The number of black nodes is the same as the number of events $|E|$. The number of black links is a tuning parameter. The occurrence frequency of the dummy events is smaller than that of the original events. The dummy events do not appear as black nodes. The tuning parameter is adjusted to make the number of clusters C. The number of red nodes is zero. Finally, the number of red nodes is increased gradually so that the all black node clusters are connected. The dummy events become red nodes between the black node clusters.

4.3 Evaluation

We present a basic evaluation of the crystallization algorithm using test data generated from a scale-free network [2]. The scale-free network is a commonly used model to describe human's communication, relationship or dependence in social problems. The scale-free network is suitable as a model for analyzing and harnessing risk. The scale-free network tends to contain centrally located hub events like leaders in an organization. The hub events influence the way the network operates. However, random deletion of events has little effect on the network's connectivity and effectiveness.

Figure 2 shows a scale-free network having 101 events. It includes a primary hub event (labeled 0-00) and five clusters (labeled 1-xx, 2-xx, 3-xx, 4-xx, and 5-xx). The clusters include secondary hub events (labeled 1-00, 2-00, 3-00, 4-00, and 5-00) and 95(= 19×5) events. The event is connected with events in different clusters by the probability of 0.02. The occurrence frequency distribution of nodal degree is ruled by the power law; $y \propto x^{-2.7}$. The evaluation is for the crystallization algorithm rather than for the whole annealing process. Human's interpretation can not be applied because the scale-free network here does not have any understandable background context. The objective is to evaluate how much information regarding the primary hub event the

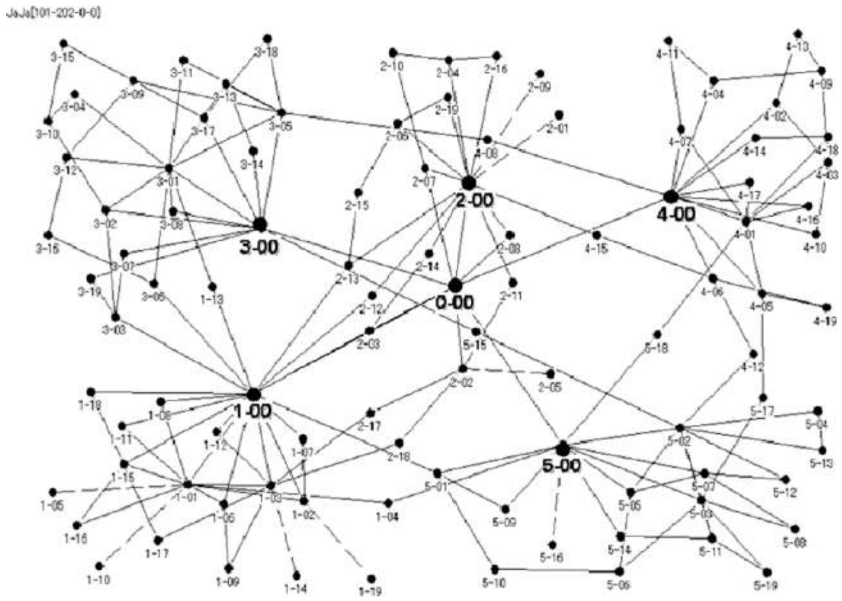

Fig. 2. Scale-free network with a primary hub event and five clusters. The clusters include secondary hub events and 95 events. The event is connected with events in different clusters at a probability of 0.02. The occurrence frequency distribution of nodal degree obeys the power law.

crystallization algorithm can recover from the test data. The test data was generated in the two steps below.

- Step 1: One hundred basket data was generated from the scale-free network.
- Step 2: A latent structure regarding the primary hub event for the evaluation was configured to the basket data.

Events under a direct influence from an event are grouped into a basket. For example, we can imagine a situation where a person starts talking and a conversation takes place among neighboring persons. The area of such influence is specified approximately with the distance from an event. In this evaluation, we made up one hundred basket data consisting of events within two hops from an individual event in Figure 2. One hop is as long as one edge on the graph. Next, from the basket data, the primary hub event (0-00) was deleted so that the hub event was made invisible on the basket data. As a result, the primary hub event and the links inter-connecting the hub event and the five clusters became a latent structure hidden behind the basket data.

At first, we present a graphical result with a KeyGraph event map. Figure 3 shows an event map, resulting in 50 crystallized dummy events (pale bridges) inter-connected to 6 event clusters. The number of vertices in the clusters is still 100. The number of pale bridges was 50. Five large clusters correspond to the original 5 clusters in figure 2. Dummy events DE-35, DE-80, and DE-89 appeared between the two clusters. Thus, the basket data containing DE-35,

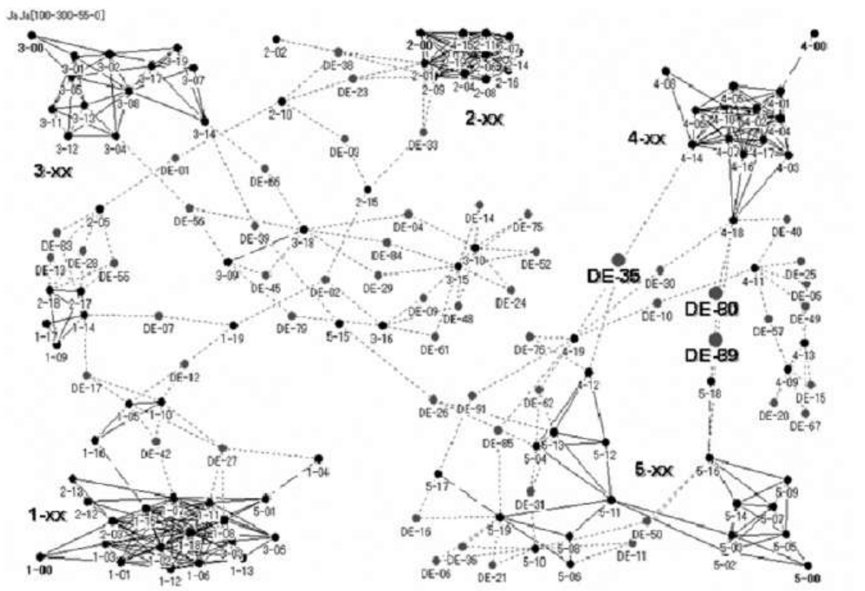

Fig. 3. The second iteration of the annealing process, resulting in fifty dummy events inter-connected to six event clusters.

DE-80, and DE-89 shall have additional relevant information on the latent structure. Actually, these basket data had contained the primary hub event before it was deleted. At least, three baskets were identified, from which we would obtain a clue regarding the invisible primary hub event. From these results, we confirmed that basket data containing dummy events appearing as pale bridges between large event clusters indicate relevant information on the latent structure. The crystallization algorithm can recover information from the test data.

Next, we present quantitative performance evaluation to see whether the crystallization algorithm can output dummy events on the event map as a correct answer. In information retrieval, precision and recall have been used as evaluation criteria. Precision is the fraction of relevant data among the all data returned by search. Here, precision is evaluated by calculating the ratio of correct dummy events within all the dummy events emerging as pale bridges on the event map. The correct dummy events are those which were inserted to the basket data where the primary hub event had been deleted. In other words, they are those relevant to understanding the latent structure. Recall is the fraction of the all relevant data that is returned by the search among the all data. Recall is evaluated by calculating the ratio of correct dummy events emerging as pale bridges on the event map among the all correct dummy events. With precision and recall, we check whether the all dummy events and the only dummy events relevant to the primary hub event are picked up and visualized as pale bridges on the event map.

Figure 4 shows the calculated precision and recall as a function of the number of visible dummy events emerging as pale bridges. These results are under the same conditions as in figure 3 (six event clusters). The precision is 80% to 90%, when the number is less than 25. The first 25 dummy events correspond to the essential parts of the latent structure. It must be noted that the remaining 25 dummy events become noisier. This observation could be a heuristic rule to prioritize the dummy events to start analysis with.

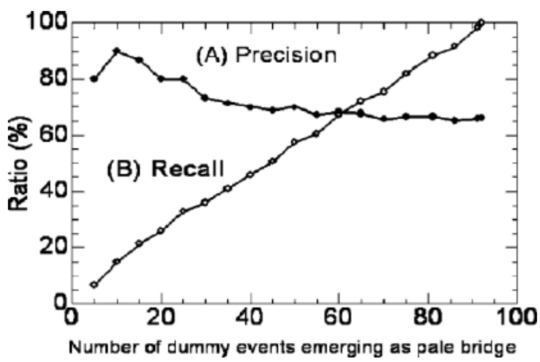

Fig. 4. Precision and recall of dummy events as a function of the number of visible dummy events under the same condition as in figure 3.

5 Human interpretation

The human interpretation starts with putting annotation to clusters. Then, it proceeds to understand dummy events made visible by the crystallization algorithm. Some heuristic rules are referred to, to extract relevant areas from the event map.

5.1 Annotation

Annotation is additional information associated with a particular piece of data or a set of data in information. Annotation is a metadata including notes, comments, explanation, reminder or hints. It is useful to put annotations on the event map as a text in order to transfer one reader's interpretation to the other readers. Its principal function is, however, to convert the ambiguous awareness from intuition into an explicit and concrete understanding for the reader's own purposes.

The human interpretation starts with putting annotation to clusters. Clusters on an intuitively natural event map usually represent a single concept in human recognition. In other words, it constitutes a dimension in a human recognition space. As the size of clusters increases, it gets easier to put annotation because larger clusters include more events and more information. Putting annotation from larger clusters to smaller clusters is a task to put aside human recognition and to configure the reader's own human recognition space. Next, human interpretation proceeds to understand dummy events on the event map. We need to know which dummy events to focus on initially. There are a few heuristic rules to start with. They are described next.

5.2 Heuristic rules for understanding

A heuristic rule is an empirical rule of thumb which usually produces a good solution or solves a simplified problem that contains the solution of complex problems. It often ignores whether the solution can be proven to be correct. But heuristic rule approach is effective when the problem is to complicate to define and treat mathematically, such as those in human knowledge, human recognition or human-computer interface. We have accumulated and confirmed some heuristic rules to extract a relevant structure from the event map after the annealing. The relevant structure the following heuristic rules indicate should be focused on to start investigation to imagine a scenario. It is also recommended to investigate the basket subject and content associated to the dummy events appearing in the focused structure.

- Heuristic rule 1: Imagine a scenario by carefully looking at the structure where many dummy events emerge as pale bridges between event clusters.

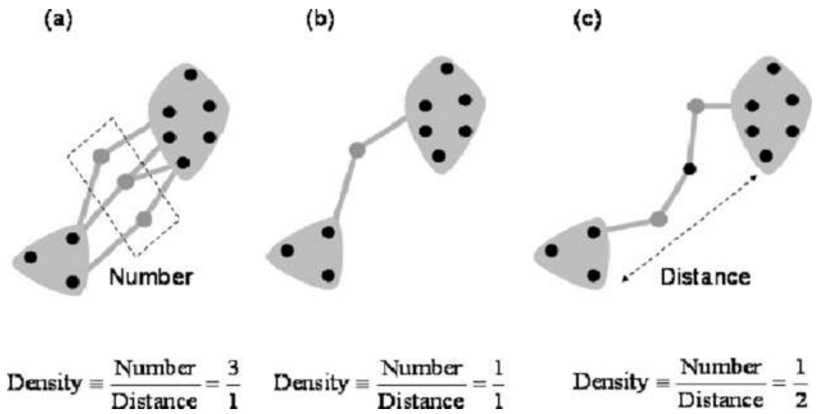

Fig. 5. Latent structures having different density index. The importance is evaluated with the ratio of the number of dummy events to the distance between event clusters. Case (a) is more important than case (b). Case (b) is more important than case (c).

- Heuristic rule 2: Imagine a scenario by carefully looking at the structure where dummy events emerging as pale bridges are directly connected to a big event cluster.

Based on the heuristic rules, a generic density index to rank the importance of the latent structure has been derived. For individual gaps between clusters, the density index is the ratio of the number of dummy events to the distance between event clusters across the dummy events. The distance is the number of red nodes along the path from one cluster to another. Figure 5 illustrates the definition of the density index. According to the index, case (a) (index = 3/1) is more important than case (b) (index = 1/1). Case (b) is more important than case (c) (index = 1/2). The density index tells us to start investigating areas where the dark events are dense like in the case (a) and to understand the meaning of dark events in reference to the annotations put to the connected event clusters.

Relevant scenarios are lead by combining understood features of the dark events, problem specific knowledge, and experiences. Within the scenario, we shall get an insight into practical hypothesis beyond observation. The hypothesis may account for an influence from an unknown leader or a technology disruption by an unknown niche company. If the latent structure looks intuitively understandable, the human interpretation terminates the iteration in the annealing process.

6 Harnessing risk in the real world

Two demonstration is carried out to test the applicability of the annealing along with crystallization algorithm to the real world social and business problems. The first demonstration is an experiment on human network analysis. The latent structure is an invisible leader hidden in a mailing list for group based decision-making. The condition is similar to discovery a hidden leader in a terrorist organization. The second demonstration is an analysis on patents for technology research and development. The latent structure is an invisible emerging technological element. It is a trial for analysis on unknown emerging technology. Both are important examples in harnessing risk in the real world.

6.1 Discovery of an invisible leader

An experiment has been demonstrated to test the applicability of the whole human-interactive annealing process to social and business problems in the real world. The experiment is on human network analysis where we try to discover an invisible leader in a communication network with the annealing process. The latent structure is a chain of command from the invisible leader in a mailing list under a group-based collective decision-making circumstance. The invisible leader had a large influence on the discussion and opinions from individual members. A communication environment was prepared so that the invisible leader could instruct the individual members toward a favorable conclusion, orally without using the mailing list. During one month, 15 members participated in the mailing list, 220 emails were sent, and 56 basket data are observed. Subjects of the basket data are the titles of emails. The contents of each basket data are a set of members who sent and replied to the emails with the subject. They shall be the input to the annealing process. For example, a basket data contains a member initiating discussion by sending an email with "subject xyz" and members replying to the email with "re: subject xyz".

The result derived from the annealing of latent structures after the third iteration is shown in figure 6. Fourteen crystallized dummy events (pale bridges) become visible. They are inter-connected to seven-event clusters or isolated visible events. The figure includes the annotations put in human's interpretation. The annotation is based on the background knowledge on the problem and understanding of the member's characteristics. Four dummy events DE-07, DE-33, DE-35, and DE-45 appeared between a seven-member event cluster (Maeno, Ohsawa, Kushiro, Murata, Hashizume, Saito, and Murakami) and a single-member event (Horie). This area is important as the heuristic rules and density index evaluation of dark events in section 5.2 indicate. Table 1 shows the subjects and contents of the basket data including the four dummy members. Table 1 shows the actual commands from the invisible leader. Comparing the subject and email text with the detail of the actual commands, we confirmed that eight of twelve commands were successfully revealed by the four dummy events. From this analysis, precision is $100\%(= 4/4)$ and recall is $67\%(= 8/12)$. These eight commands seem more important than others in terms of an effort to converge the discussion into conclusion. The annealing process accurately leads to the answer. Although the numbers 4 and 8 are

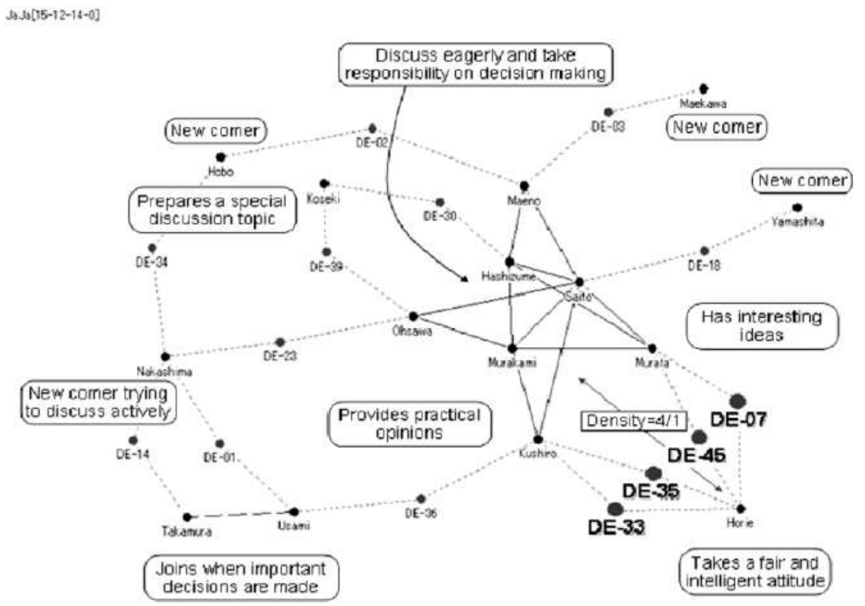

Fig. 6. Crystallized dummy events in the experiment with a mailing list to make a decision collectively under an invisible leader.

small, this is a sound evidence of the performance, under the restriction where the invisible leader speak rarely. The experiment was successful in revealing the following two latent structures.

- *Instructions in Command*: The fact was as shown in table 1. The result was that the four subjects suggested by the dummy events were included in the commands. The annealing process revealed communication among the four dummy events representing the invisible leader and the members.

- *Chain of command*: The fact was that the invisible leader had sent commands primarily to members in a seven-member event cluster and a single-member event. The result was that the edges stemming from the four dummy events were along the commands. The annealing process revealed the chain of command from the invisible leader to the members. It is consistent with the annotations on observed characteristics of the members. From the intuitive observation, we were got convinced that the invisible leader should primarily contact with the three important members (Kushiro, Murata, and Horie) in the clusters.

Popular approaches in the present human network analysis are based on a network or graph theory. Scale-free networks [2], or small worlds [21] have been successful in describing many features of human activities and interactions. In addition to describing the human networks accurately, inferring a latent structure behind observation is getting more important. Such problem examples

Table 1. Subjects and content of the basket including the four dummy members crystallized in figure 6.

Dummy event	Subject (email title)	Content (email sender and replier)
DE-07	Assign roles	Hashizume, Horie, Maeno, Murakami, Murata, Ohsawa
DE-33	Determine place	Hashizume, Horie, Kushiro, Maeno, Murakami, Saito
DE-35	Announcement on setup	Horie, Kushiro, Maeno, Murakami
DE-45	Voting on plans	Hashizume, Horie, Maeno, Murakami, Murata, Ohsawa, Saito

Table 2. Actual commands from the invidible leader to the members.

No	Command from the invisible leader	Does it match the four dummy events ?
1	Announce about this mailing list	No
2	Invite new comers from outside	No
3	Introduce yourself	No
4	Make sub-groups to discuss individual topics	Yes (DE-07)
5	Play a role as a leader of a sub-group	Yes (DE-07)
6	Start discussion to assign tasks	Yes (DE-07)
7	Focus on particular subjects	No
8	Discuss on the place	Yes (DE-33)
9	Draw a conclusion on the recipe	Yes (DE-45)
10	Draw a conclusion on task assignment	Yes (DE-45)
11	Announce the arrangement	Yes (DE-35)
12	Announce the details	Yes (DE-35)

are the assessment of an organizational communication capability, the evaluation of human relational influence in a workplace, detection of collusion in a bid, and identification of disguise or aliasing in an Internet community. The human-interactive annealing along with the crystallization algorithm is expected to shed a new light on these problems.

6.2 Discovery of an invisible emerging technology

A simple trial for analysis on patents is demonstrated. Twenty nine patents applied in Japan are picked up as known technological expertise in the field of knowledge discovery. Patents provide with technological elements representing a measure to solve a specific engineering design problem. We try to identify an unknown but significant technological element by analyzing these patents. It may be a technology hidden by a rival company like a submarine patent, an emerging technology from other field of expertise, or a technology owned by a niche company or a small technician community. These latent strucutres are potential risk to corporate research and development. Subjects of the baskets are objective or preferred effect on the engineering design problems. Content of the baskets is a set of patent application numbers which is suitable for the subjects of the baskets. Thirteen baskets are configured. They shall be the input to the annealing process.

The result derived from the annealing of latent structures after the second iteration is shown in figure 7. Seven crystallized dummy events (pale bridges) become visible. They are inter-connected to eighteen-event clusters, smaller clusters, or isolated visible events. The figure includes the annotations put in human's interpretation. The annotation is based on the comments understood from the patents. Three dummy technological elements DE-01, DE-06, and DE-07 appeared between the biggest cluster and two two-event clusters. These areas are important as the heuristic rules and density index evaluation of dark events in section 5.2 indicate.

The biggest cluster corresponds to a set of conventional measures developed for statistical analysis or data mining in knowledge discovery. Particularly, discovery of association rules in knowledge discovery has evolved along three performance criteria. The first criterion is speed. This is required in real-time and on-line applications such as a contact center for product support and services. The second criterion is the amount of data. This is required in batch processing applications such as long-term customer trend analysis. The third

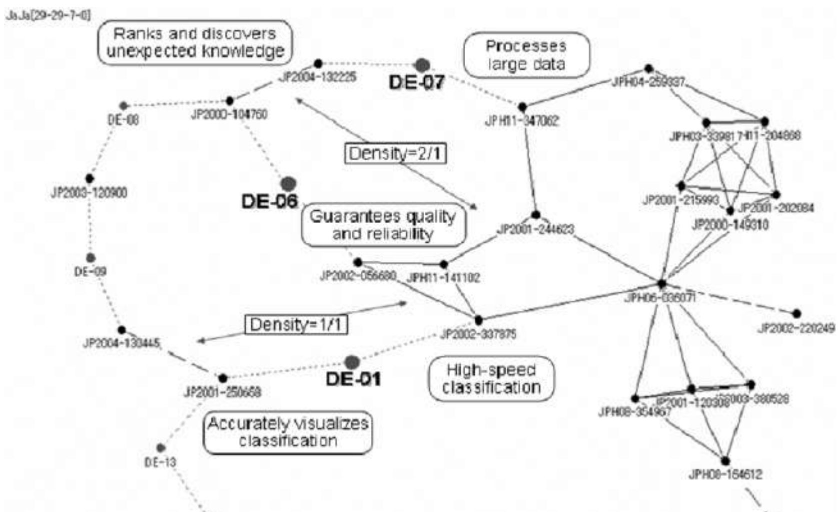

Fig. 7. Crystallized dummy events in the analysis on Japanese patents on knowledge discovery.

criterion is quality. It means that more precise and more accurate association rules are required. The two two-event clusters incorporate technological elements for discovering unexpected knowledge and for visualizing knowledge respectively. Unexpected knowledge tends to be neglected in human's recognition, but significant for decision-making. In this sense, it is related to the chance discovery. Visualization is an important technical expertise which has been employed in many fields in science and engineering. These are mentioned as annotations in the figure.

The three dummy technological elements between the clusters suggest a new and unknown technological element which combines these three clusters. Here is the answer. The human-interactive annealing, about which you are reading, is just such a technology! It indicates unexpected risk by visualizing invisible dark events with use of the technical expertise in statistics and machine learning. The technological element represents a technique to incorporate human cognitive factor into the process. The result recommends the technology analyst to investigate closely whether potential competitor companies are developing such technological element or not. Although this analysis is for a simple demonstration purpose, it indicates how we should proceed to get an insight into a scenario for harnessing risk from hidden technological property based on a latent structure.

Popular approaches in the present technology research and development employ engineering design methods such as TRIZ (Theory of Inventive Problem Solving in Russian), Value Engineering (VE), or Taguchi method. These methods mainly aim at utilizing precedent successful cases and optimizing combination of technological elements under cost and quality constraint. Identifying an invisible new technological element emerging as a niche is getting more important. The annealing along with crystallization algorithm is expected to shed a new light on such problems.

7 Summary

There are invisible events which play an important role in dynamics of visible events. Such events are named *dark events*. Understanding of the dark event is important for *harnessing risk in modern social and business problems*. Risk (or opportunity) may originate in dense dark events within a latent structure, grow into visible events or event clusters, and mature toward well-understood scenarios. To understand dark events, a new technique; *human-interactive annealing* of latent structures have been developed. The annealing process is combination and iteration of human interpretation and crystallization algorithm of dark events. Test data generated from a scale-free network showed that the precision of the algorithm is up to 90%. An experiment on discovering an invisible leader under an on-line collective decision-making circumstance was successful. The result indicates that we could discover a hidden terrorist leader and remove risk from the terrosist attacks. A trial for the analysis on patents for technology research and development were demonstrated. This could be a starting point for preparing for the impact from a hidden technology or an unknown emerging technology. The human-interactive annealing is a great advance in scenario writing where we shall get an insight into practical hypothesis beyond observation for harnessing risk in the real world.

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Mining Hospital Management Data using R

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Summary. This paper focuses on mining hospital management data, focusing on the following three questions: (1) Although the average of length of stay is usually used for a index for hospital managment, is this index the best one for hospital management? (2) Although the length of stay is correlated with hospital income, how much is the degree of dependence? (3) Does another factor have as much influence in hospital income as the length of stay? For this purpose, we analyzed the data extracted from the hospital information system in Chiba University Hospital. The results show several interesting results, including the answers of the three above questions. First. the median of length of stay is a better index than the average, the length of stay is highly correlated with hospital income, and more than 70 per cent of the variance in hospital income can be explained by that of length of stay. Finally, the length of stay is a principal factor for hospital income, which reflects the characteristics of Japanese healthcare system.

1 Introduction

It has passed about twenty years since clinical information are stored electronically as a hospital information system since 1980's. Stored data includes from accounting information to laboratory data and even patient records are now stared to be accumulated: in other words, a hospital cannot function without the information system, where almost all the pieces of medical information are stored as multimedia databases[1]. Especially, if the implementation of electronic patient records is progressed into the improvement on the efficiency of information retrieval, it may not be a dream for each patient to benefit from the personal database with all the healthcare information, "from cradle to tomb". However, although the studies on electronic patient record has been progressed rapidly, reuse of the stored data has not yet been discussed in details, except for laboratory data and accounting information to which OLAP methodologies are applied. Even in these databases, more intelligent techniques for reuse of the data, such as data mining and classical statistical methods has just started to be applied from 1990's[2, 3]. Human data

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analysis is characterized by a deep and short-range investigation based on their experienced "cases", whereas one of the most distinguished features of computer-based data analysis is to enable us to understand from the different viewpoints by using "cross-sectional" search. It is expected that the intelligent reuse of data in the hospital information system provides us to grasp the all the characteristics of university hospital and to acquire objective knowledge about how the hospital management should be and what kind of medical care should be served in the university hospital.

This paper focuses on mining hospital management data, focusing on the following three questions: (1) Although the average of length of stay is usually used for a index for hospital managment, is this index the best one for hospital management? (2) Although the length of stay is correlated with hospital income, how much is the degree of dependence? (3) Does another factor have as much influence in hospital income as the length of stay? For this purpose, we analyzed the data extracted from the hospital information system in Chiba University Hospital.

The results show several interesting results, including the answers of the three above questions. First. the median of length of stay is a better index than the average, the length of stay is highly correlated with hospital income, and more than 70 per cent of the variance in hospital income can be explained by that of length of stay. Finally, the length of stay is a principal factor for hospital income, which reflects the characteristics of Japanese healthcare system.

2 Objective

The objectives of this research is to investigate what kind of knowledge can be extracted by statistical methods from the datasets stored in the hospital information system of Chiba University Hospital, especially useful for future hospital management and decision support. Especially, since the revenue of Japanese hospital is based on NHI points of Japanese medical care, it is important to investigate the factor which determines the amount of NHI points.

3 Methods

3.1 Representation of Discharge Summaries

When the hospital information system for discharge summaries is introduced in Chiba University Hospital in 1978, a discharge summary is distributed to doctors as a paper sheet for each patient admitted to the hospital. Doctors fill in each sheet just after the patient leaves the hospital, the parts of this sheet which can be coded are stored electronically. A sheet for discharge summary is composed of the items common to all the departments and the items specific to each department. For example, the items specific to neurology consists of the results of neurological examinations and the severity of diseases. The common items consist of those in which codes or numerical values should be filled in and those in which texts should be input. After the doctor in charge fill in those items and submit to the division of medical records, the staff input codes and numerical values into a database system. These processes are continued until a new hospital information system was introduced in 2000, which means that the non-text items common to all the departments has been stored for about 20 years. There are 16 items for codes or numerical values: patient ID, the department in charge, occupation, height and weight on admission, height and weight just before hospital discharge, a motivation for visit, outcome, autopsy or not, cause of death, the date of first visit, the date of admission, the date of discharge, the name of disease (ICD-9 code [4]), treatment method. However, height and weight just before hospital discharge are not input in the database. Concerning the items specific to each department, only those of surgery and ophthalmology are stored electronically.

3.2 Extraction of Datasets from Hospital Information System

The databases in the hospital information system of Chiba University Hospital are described by MUMPS[5]. MUMPS is a programming language which can construct a database with a hierarchical structure based on a binary tree. By using the characteristics of a binary tree, each item can store several data as a tree, which makes the data management and retrieval more efficient than relational databases. Datasets for analysis are extracted from the database on discharge summaries and the database on patient basic information by using patient ID and the date on admission as keys. The program for extraction is developed by the first author due to the following reasons. Since NHI points, which stands for National Healthcare Insurance points, are stored for each patient ID and each month, the total points for each admission for each patient are calculated from NHI points for each month. The total points are combined with the dataset extracted from the discharge summaries by using patient ID and the date on admission as keys. The number of the records of the dataset extracted from the global: MRMG, which is a database on discharge summaries, is 157,636 for 21 years from 1978.4 to 2000.3. The time needed for computation is about one hour by SUN Workstation (Enterprise 450). Concerning the dataset combined with NHI points, the number of the records is 20,146 for three years from 1997.4 to 2000.3.

3.3 Methods for Statistical Analysis

Descriptive statistics, exploratory data analysis and statistical tests were applied to the dataset extracted only from the discharge summaries for the analysis of patient basic information (gender, age and occupation), outcome, the number of the days in hospitals and diseases, including their chronological trends. Concerning the datasets combined with accounting information for three years (1997.4 to 2000.3), the relations among NHI points and items in the discharge summaries were analyzed by descriptive statistics, exploratory data analysis, statistical tests, regression analysis and generalized linear model. R was used for these analyses.

4 Results

Due to the limitation of the spaces, the most interesting results are shown in this section. In the subsequent subsections, the results of the whole cases, and two levels of ICD-9 code, called major and minor divisions, are compared. Especially, concerning the results for the major and minor divisions, malignant neoplasm and the following three largest minor divisions of the malignant neoplasm are focused on: neoplasm of trachea, bronchus, and lung, neoplasm of stomach, and neoplasm of liver and intrahepatic bile ducts. In the subsequent sessions, neoplasm of lung, stomach and liver denotes the above three divisions for short.

4.1 Distribution of Length of Stay

Fig. 1 shows the distribution of the length of stay of the whole cases, which skewed with the long tail to the right. Thus, the logarithm of the length of stay is taken to tame this skewness. Fig. 2 gives the result of this transformation, whose distribution is very close to normal distribution: this means that the distribution of the whole cases is log-normal. This observation holds even when the major divisions are taken as sample. It is notable that the nature of this distribution holds even in the minor divisions, three largest three diseases.

Table 1 summarizes the descriptive statistics of length of stay with respect to the whole cases, major and minor divisions. The natures of these distributions are not significantly changed ifthese cases are stratified by the condition whether a surgical operation is applied to a case or not.

4.2 Distribution of NHI Points

Since the variance of raw data of NHI points are very large and the distribution is skewed, the raw data are transformed into the "median index", which is defined as the ratio of the total points to the median of the whole cases. Fig. 3 and Fig. 4 show the distribution of the raw data and that of the logarithm of the raw data of median index. Those figures suggests that the NHI points of the whole cases follow log-normal distribution. On the other hand, the distributions for minor divisions are different. The same observations are obtained from the distribution of NHI Points of Neoplasm.

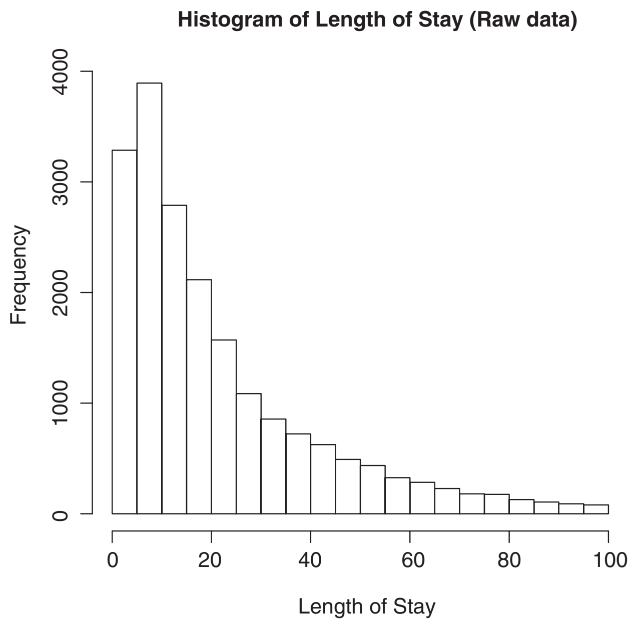

Fig. 1. Distribution of Length of Stay (Raw Data, Total Cases)

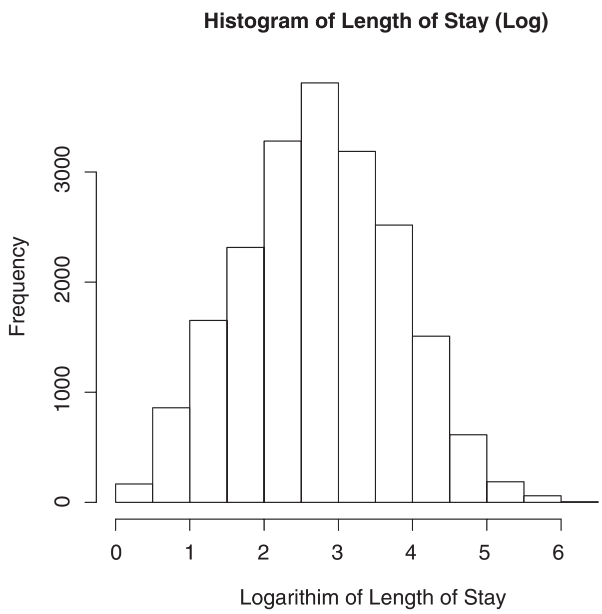

Fig. 2. Distribution of Length of Stay (Logarithm Transformation, Total Cases)

Table 1. Descriptive Statistics of Length of Stay

	Average	Median	SD	Skewness	Kuritosis
Whole Cases					
Raw Data	26.46	16.00	33.67	4.34	34.15
Logarithmic Transformation	2.74	2.77	1.06	-0.06	-0.28
Neoplasm					
Raw Data	37.54	25.00	38.72	2.90	13.21
Logarithmic Transformation	3.19	3.22	0.98	-0.32	0.08
Malignant Neoplasm of Lung					
Raw Data	49.65	39.00	43.42	2.57	10.82
Logarithmic Transformation	3.57	3.66	0.88	-0.79	2.00
Malignant Neoplasm of Stomach					
Raw Data	36.44	36.00	19.18	0.46	0.37
Logarithmic Transformation	3.40	3.58	0.72	-1.42	2.55
Malignant Neoplasm of Liver					
Raw Data	35.93	33.00	21.40	1.19	2.70
Logarithmic Transformation	3.38	3.50	0.71	-1.18	3.03

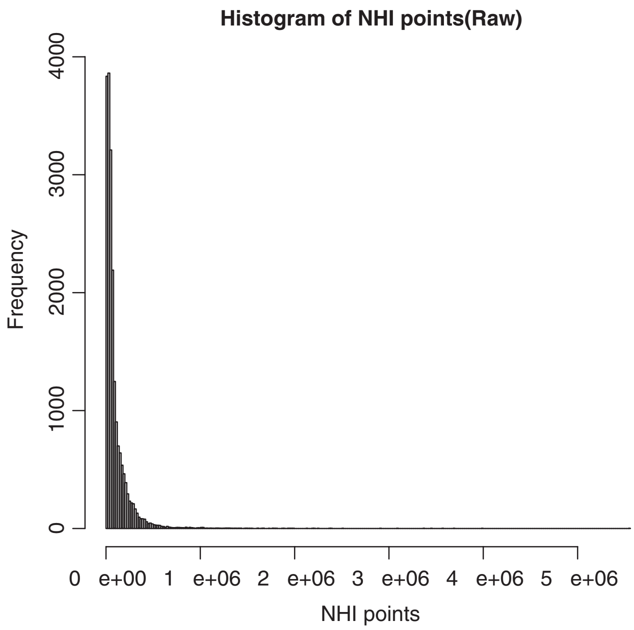

Fig. 3. Distribution of NHI Points (Raw Data, Total Cases)

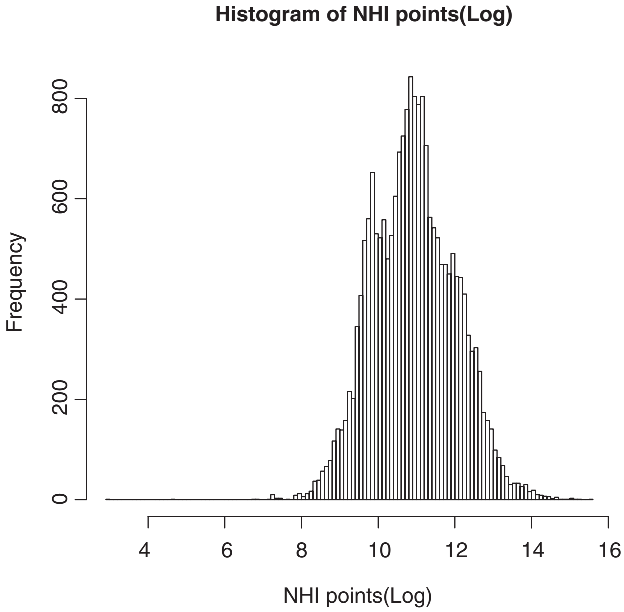

Fig. 4. Distribution of NHI Points (Logarithm Transformation, Total Cases)

4.3 Correlation between Length of Stay and NHI Points

Fig. 5 and Fig. 6 depicts the scattergram between the length of stay and NHI points of total cases and neoplasm cases which suggest high correlation between two variables. For simplicity, the vertical and horizontal axes show the logarithm of raw values. Actually, The coefficient of correlation are calculated as 0.837 and 0.867, which mean that the correlation is very strong.

Table 2 summarized the correlation coffecients between NHI points and Length of Stay with respect to the whole cases, neoplasm and three major types of malignant neoplasm: lung, stomach and liver. Comparison of the coefficient of correlation between the group with and without a surgical operation shows that the group without an operation has higher correlations than that with an operation, which suggests that NHI points of the treatment methods other than surgical operations should be strongly dependent on the lengths of stay.

4.4 Generalized Linear Model

Since all the items except for the length of stay are categorical variables, conventional regression models cannot be applied to the study on relations between NHI points and other items. For this purpose, generalized linear model [6] was applied to the dataset on combination of accounting data and

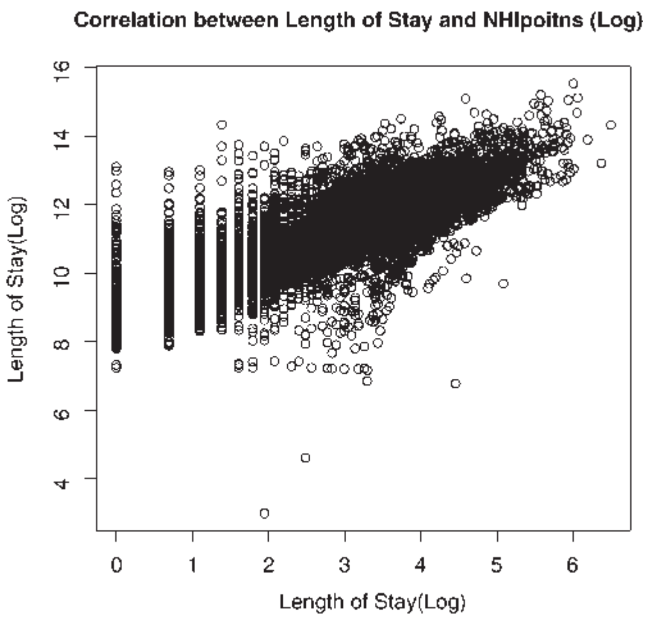

Fig. 5. Scattergram of Length of Stay and NHI Points (Logarithm Transformation, Total Data)

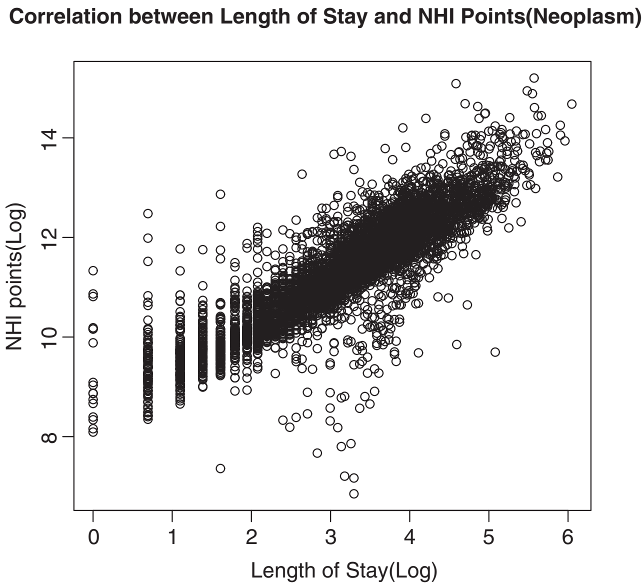

Fig. 6. Scattergram of Length of Stay and NHI Points (Logarithm Transformation, Neoplasm)

Table 2. Correlation between Length of Stay and NHI Points (After Logarithm Transformation)

	Total	With Operation	Without Operation
Total Cases	0.837	0.829	0.779
Neoplasm	0.867	0.844	0.826
Lung Cancer	0.838	0.648	0.903
Stomach Cancer	0.827	0.738	0.801
Liver Cancer	0.711	0.577	0.755

discharge summaries. NHI point was selected as a target variable and the following four variables were selected as explanatory variables: outcome, treatment method, major division of ICD-9 codes and the categorized length of stay. The length of stay is categorized so that the distribution of the transformed variable is close to normal distribution, where the width of windows is set to 0.5 for the logarithmic value of the length of stay. Treatment, outcome and major divisions of ICD codes are transformed into dummy variables to clarify the contributions of these values to a target variable. For example, the outcomes of discharge are split into the following six dummy variable: D1: recovered, D2: improved, D3: unchanged, D4: worsened, D5: dead and D6: others. Fig. 7 shows the results of GLM on the total cases, whose target variable is NHI points. All the variables are sorted by the F value. The most contributing factor is the length of stay, whereas the contributions of the other factors are small.

Figure 8 gives the results of GLM on major division (malignant neoplasm), and three minor divisions, whose target variable is NHI points. Compared with Fig. 7, the number of the factors which gives the significant contributions to NHI points are very small, which suggest that the variabilities of NHI points in major and minor divisions are very low, compared with that of total cases.

5 Conclusion

This paper analyzes the following two datasets extracted from the hospital information system in Chiba University Hospital. One is the dataset extracted from the database on discharge summaries stored for about twenty years from 1978 to 2000. The other is combination of data from discharge summaries and accounting information system. The analysis gave the following results: (1) malignant neoplasm is the first major category which determines the profitability of Chiba University Hospital, which is stable for twenty years. (2) In a global view, the length of stay is the principle factor for the revenue of the hospital, whose distribution follows the log-normal distribution. (3) Treatment method may be a secondary factor to determine the distribution of the length of stay for each disease, which may be correlated with the property that the length of stay follows

```
Call:
glm(formula
    = lognhi0 ~ (loglos0 + sex + age + outcome + adtime)^2,
    data = table)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-7.17179  -0.34257  -0.05306   0.26980   4.37032

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)      8.5134576  0.0517890 164.388  < 2e-16 ***
loglos0          0.8556933  0.0160016  53.476  < 2e-16 ***
sexM             0.1609546  0.0405073   3.973 7.12e-05 ***
age             -0.0038052  0.0008674  -4.387 1.16e-05 ***
outcome         -0.0083361  0.0181751  -0.459 0.646487
adtime          -0.0071641  0.0207570  -0.345 0.729992
loglos0:sexM    -0.0076588  0.0094779  -0.808 0.419061
loglos0:age      0.0006624  0.0001925   3.441 0.000581 ***
loglos0:outcome -0.0081192  0.0048621  -1.670 0.094960 .
loglos0:adtime  -0.0091114  0.0052452  -1.737 0.082392 .
sexM:age        -0.0003907  0.0004071  -0.960 0.337163
sexM:outcome    -0.0265756  0.0117403  -2.264 0.023611 *
sexM:adtime      0.0049953  0.0110712   0.451 0.651850
age:outcome      0.0011690  0.0002427   4.816 1.48e-06 ***
age:adtime       0.0011459  0.0002167   5.289 1.25e-07 ***
outcome:adtime   0.0136464  0.0056265   2.425 0.015304 *
---
Signif. codes:
        0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for gaussian family
         taken to be 0.3421949)

    Null deviance: 18087.9  on 15425  degrees of freedom
Residual deviance:  5273.2  on 15410  degrees of freedom
AIC: 27253

Number of Fisher Scoring iterations: 2
```

Fig. 7. GLM Anaysis on NHI Points (Total Cases, Logarithmic Transformed Data)

```
glm(formula
     = lognhi ~ (loglos + sex + age + outcome + adtime)^2,
    data = data_tumor)

Deviance Residuals:
      Min         1Q     Median         3Q        Max
-4.254140  -0.253159  -0.006586   0.257345   3.272261

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)     8.3787405  0.1231678  68.027  < 2e-16 ***
loglos          0.9676587  0.0318115  30.419  < 2e-16 ***
sexM            0.0635790  0.0850749   0.747   0.4549
age            -0.0006800  0.0018249  -0.373   0.7095
outcome         0.0149955  0.0366230   0.409   0.6822
adtime          0.0212879  0.0319450   0.666   0.5052
loglos:sexM     0.0270253  0.0161205   1.676   0.0937 .
loglos:age     -0.0005277  0.0003898  -1.354   0.1758
loglos:outcome  0.0109782  0.0071636   1.532   0.1255
loglos:adtime  -0.0412971  0.0086875  -4.754 2.06e-06 ***
sexM:age       -0.0017424  0.0008612  -2.023   0.0431 *
sexM:outcome   -0.0042336  0.0172197  -0.246   0.8058
sexM:adtime     0.0017416  0.0188084   0.093   0.9262
age:outcome    -0.0007851  0.0004409  -1.781   0.0750 .
age:adtime      0.0018626  0.0003839   4.852 1.26e-06 ***
outcome:adtime  0.0053574  0.0072173   0.742   0.4579
---
Signif. codes:
         0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for gaussian family
   taken to be 0.2561771)

    Null deviance: 4940.4  on 4729  degrees of freedom
Residual deviance: 1207.6  on 4714  degrees of freedom
AIC: 6999.4

Number of Fisher Scoring iterations: 2
```

Fig. 8. GLM Anaysis on NHI Points (Neoplasm, Logarithmic Transformed Data)

log-normal distribution for each minor division in total. (4) Treatment without a surgical operation should be more examined by additional information, which is also important to evaluate the profitability of the university hospital.

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