Toward Extenics-Based Innovation Model on Intelligent Knowledge Management

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Abstract Innovation is playing an increasingly important role in management, but the process of generating creative ideas for innovation mostly relies on skilled persons which are usually unavailable. Information technology is changing the management environment and accumulating huge data, from which data mining discovered a lot of knowledge. However, it's difficult to use such rough knowledge and information effectively to benefit the innovation. Based on the new cross discipline Extenics, we analyzed on current innovation models and methods, and present a combined innovation model using intelligent knowledge management and extension transformation methods. The model process the knowledge discovered from data mining into a tree structure and save them in knowledge base in basic-element format. We then explore the innovation paths and its directions by a formularized model by human-computer interaction method based on Extenics. The model can objectively describe how the innovation solutions are created. Furthermore, we present a management innovation case to support our model. The framework is proved useful for practical applications.

Keywords Extension innovation · Intelligent knowledge management · Data mining · Extenics

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1 Introduction

Today's internet environment provides an excellent opportunity for innovation. According to Wikipedia, "Innovation is the development of new values through solutions that meet new requirements, inarticulate needs, or old customer and market needs in value adding new ways. This is accomplished through more effective products, processes, services, technologies, or ideas that are readily available to markets, governments, and society." (<http://en.wikipedia.org/wiki/Innovation>). Innovation achievements are the basis for progress in our world. Today's organizations operate in an environment that is rapidly and continuously changing and uncertain due to global competition, information explosion and advances in web technology and telecommunication. Innovation capability is one of the key factors for innovation, which plays a great role in the economic growth and success of companies, accompany with significant contribution to new product development and core competence construction [32].

However, contrast with many methods about innovation, most existing literature lack analysis of origins and generative processes of innovation capability [3]. Moreover, the analysis about innovation capability is limited to the level of qualitative analysis, lacking the support of quantitative analysis. Most literatures view the processes of innovation process as a black box. This greatly prevents the progress in innovation. Several scholars pay attentions to presenting models of processes [2,9], but the models give no enough and clearly explanation about the micro-level processes of the occurrence of innovation. Current innovation processes mostly rely on experience and background knowledge by creative thinking [37]. The process of innovation needs more scientifically support [20].

Extension theory (extenics) is founded to solve contradictory problems by formalization methods based on the concepts of matter-element (physical things) and extension set, which combines qualitative presentation and quantitative analysis together [47], extenics provides a new view for understanding the process of innovation. But it needs more support by information technology.

Information & Communication Technology (ICT) tools have experienced tremendous changes in last decades. Many research trends could be observed that are likely to provide new innovation approaches and effective means to support such new innovation processes [41]. In the era of World Wide Web, Information Technology (IT) applied in business has accumulated huge data and information. Knowledge discovered by data mining is novel and quantitative, however, it's difficult to use so much knowledge and information effectively for decision making and benefit the innovation [28]. It is a challenge for looking inside the process of innovation based on intelligent knowledge management [22].

Intelligent knowledge management using large data bases and enables to generate "special" knowledge based on the hidden patterns created by data mining [21,40,53]. The process of intelligent knowledge management is from *original* data, *rough* knowledge to *intelligent* knowledge, and *actionable* knowledge as well as the wisdom [51]. Innovation needs tools and methods [18]. The interaction research with intelligent techniques' supports methods for innovation is necessary at present. Intelligent knowledge management is one of the best information technologies to support innovation.

To overcome such shortages and improve the innovation capability scientifically, we propose a new innovation model that would support the company to effectively use IT in innovation procedures and improve the innovation capability in management. We collect data systematically based on basic element theory, and then discover quantitative knowledge by data mining. We then transform the information and knowledge by extension method qualitatively to obtain solutions in a computer-human interaction way. Therefore, the innovation process is no more darkness and we can improve the team work efficiency in innovation activities. The rest of the paper is organized as follows. Section 2 discusses the concepts of the main existing innovation methods and knowledge management technology for reference. Section 3 provides a systemic model for preparing the data for input. Section 4 presents a framework and process about utilization of Extenics to generate innovative solutions combined with intelligent knowledge management. Section 5 presents a case study of management, followed by a brief summary and some future research scopes in Sect. 6.

2 Literature Review

2.1 Innovation Factors

Innovation is influenced by many variables, the basis for creativity is held to involve the production of high-quality, original, and elegant solutions [1,10] to complex, novel, ill-defined, or poorly structured, problems [29]. What allows people to generate high-quality, original, and elegant solutions to complex, novel, ill-defined problems [25,42]? Innovation cannot be understood using a single simple model. However, creativity can be understood, or explained using a variety of substantive models. Innovation involves multiple, complex, processing operations. Effective execution of these processes depends on the knowledge available to the person and the strategies people employ in executing these processes [39]. The operation of multiple processes, multiple strategies, and multiple knowledge structures makes it difficult, albeit intriguing, to formulate an understanding of innovation [17], so intelligent technology is necessary for improving innovation capability.

2.2 Innovation Methods

There are many methods for creative thinking and benefit innovation. NM method based on HBC Model [27], divides human memory into “point memory”, which is daily accumulated through association, reverse thought or analogy and “line memory”, which is new combinations of “point memory” to spring up new creative ideas.

Brainstorming is probably the best known of all the techniques available for creative problem solving. Brain Storm [34] makes participants be enlightened by others. On the other way, the Delphi method develops solutions through a systematic, interactive process between panels of experts which are separated [23]. Syntectics method [15], which is developed by MIT professor William Gordon, would extract abstract questions from concrete situation and put forward for participants along with the process of discovering the links between different and apparently irrelevant elements (analogy).

But It is not easy to set out systematic procedures for organizing effective brainstorming sessions and evaluating the ideas produced [36] because brainstorming mostly rely on participants' experience and knowledge.

"5W2H" (Why, What, Where, When, Who, How, How much), Osborn Checklist method [34] and Attribute Listing Technique (ALT) take advantage of specifiable questions to enlighten personal thought and decrease pretermision. Checklist method checks 9 angles, including other usages, rearrangement, modification, magnification, minification, substitution, adaption, reversal and combination, to generate new ideas and novel solving strategies. ALT would list all the key attributes and breaks the problem down into smaller and smaller bits to figure ways out [11]. As an extension of Attribute Listing, Morphological Analysis [56] is a method for systematically structuring and investigating the total set of relationships contained in multi-dimensional, usually non-quantifiable, problem complexes.

As a group creativity technique designed to generate a large number of ideas for the solution of a problem, Six Thinking Hats [12] combines with the idea of parallel thinking, provides a means for groups to think together more effectively.

Other methods or techniques include Lotus Blossom Technique, Ideatoons Blueprint, Neuo-Linguistic Programming Techniques (NLP) etc., Mind Map would be a useful tool for organizing these creative ideas and stimulating more thinking [4].

These innovation methods makes use of various approaches to stimulate innovation of individuals or a group of experts/team members, along with huge amounts of spend of time, fund and human resource. The Iterative, anthropic, circumstances-oriented processes result in low efficiency and severe dependence upon personal intelligence which would subject to limitations of individuals themselves [43], hamper the future inheritance and keep out of step under the rapidly changed information and knowledge era.

2.3 Innovation Process

Over the last few decades, the nature of innovation in management has changed from being primarily related to incremental product innovation towards more business model innovation, discontinuous innovation and open innovation. These changes impose new demands on the ideation phase of the innovation process and on idea management systems. As noted by Sandstrom and Bjork [38], the studied idea management system is dual, i.e., aiming to generate, evaluate and select both continuous and discontinuous innovation ideas and employing different processes and criteria within the same system.

Mumford et al. [30] presented eight core processes for the effective execution of innovation: (a) problem definition, (b) information gathering, (c) information organization, (d) conceptual combination, (e) idea generation, (f) idea evaluation, (g) implementation planning, and (h) solution monitoring. Effective execution of these processes, in turn, depends on people applying requisite strategies during process execution and having available requisite knowledge.

As a theory of inventive problem solving, TRIZ was developed by the Soviet inventor Genrich Altshuller and his colleagues at 1946. It was based on the study of patterns

of 2.5 million global invention patents. The theory systematically applied strategies and tools to generate superior solutions which resolve contradictions in technological inventions, with a set of 40 inventive principles and later a Matrix of Contradictions with 39 system factors [19].

Extenics-based innovation models focus on solving incompatible problems by formalized methods in management and engineering. Zhou and Li [54] put forward the Extenics-based enterprise independent innovation model and its implement platform. Although it have solved many engineering incompatible problems [24, 52], most practice methods are suitable for special field, there is no systematic theory on knowledge based innovation yet. Extension innovation methods will need further improvement on general operable methods for innovative activities of all fields [48].

2.4 Data Mining and Knowledge Management

Data mining discovers knowledge and rules from large numbers of data. They are connotative, unknown, which are likely to be interested, and to have latency values for decision making [16]. Today data mining has been widely applied in business [33].

Combining Extenics with data mining, a new methodology called Extension data mining (EDM) [8] has been built up. The main task of EDM is to acquire the transformation knowledge to help for better decisions. It takes advantage of extension methods and data mining technology, explores to acquire the knowledge based on extension transformations. Meanwhile EDM can acquire extensible classification knowledge and conductive knowledge. Such kinds of data, information and knowledge gathering together, we have to do deep research on how to select proper knowledge for innovation systematically.

Tools at all levels rely on ontologies which refer to consensual, shared, formal descriptions of important concepts in a domain to provide structural and semantic definitions of documents [14]. Wang et al. [45] proposed an ontology-based knowledge integration approach to solve the problem of knowledge integration difficulty and achieve design knowledge sharing and reuse for the designers. They transformed the problems of design knowledge integration into knowledge ontology integration problems, and through the establishment of global ontology and local ontology to implement knowledge integration, include (1) Technical knowledge, (2) Characteristic knowledge, and (3) Managerial knowledge. Ontology-based knowledge integration model of collaborative consists of resource layer, local ontology layer, global ontology layer, visualization layer and application layer. The focus is on the individual as the basis or creator of knowledge [35].

Declarative knowledge, factual, information and cognitive schema are commonly involved in most forms of complex performance including innovation [13]. Nousala et al. [31] prototyped a methodology based on mind mapping and a relational database to codify, index and map staff knowledge. This includes an interview process to build trust while eliciting career histories, plus a relationally based graphical knowledge retrieval structure making it easy for other staff to determine who is likely to possess the kind of knowledge needed [50].

Fig. 1 Problems of current innovation models

2.5 Problem Solving Models

Saaty [37] makes an original and very fundamental contribution to creative thinking and problem solving with its discussion of order and priority that are an integral part of the subject. The process includes recognizing problems, formulating problems, solving problems and analyzing the impact of the solution, for each step he gives guidelines in detail which is useful.

Marzano et al. [26] provide a framework intended to help educational practitioners plan programs for incorporating the teaching of thinking throughout the regular curriculum from diverse sources, including philosophy and cognitive psychology in their book. It discusses five dimensions of thinking: (1) metacognition; (2) critical and innovation; (3) thinking processes—such as concept formation, problem solving, and research; (4) core thinking skills—the “building blocks” of thinking—including focusing, information-gathering, organizing and generating skills; and (5) the relationship of content-area knowledge to thinking.

Information technology affects and influences people to make decisions. IT is useful in solving routine problems but not as obvious in solving fuzzy and challenging problems. To solve fuzzy and challenging problems, an effective concept and model of competence set analysis is introduced. IT impacts on a variety of decision problems including routine problems, mixed routine problems, fuzzy problems and challenging problems [49].

These above methods have expanded the limitation of personal intelligence. However, from the practical view, these methods still remain 3 problems unsolved as shown in Fig. 1:

1. Information and knowledge input for innovation is mostly unclear.
2. The innovation process remains a black box and we are not clear on how innovation happens.
3. Many innovation solutions is created rely on luck or even by accident and we can't obtain all-viewed possible solutions systematically.

Also, no methods break the black box of innovation solutions generating processes. They potentially limit the application scope to particular design domain or problem solving, with ignoring the usage of Information Technologies, Web platform for instance. The data and information is so huge that they are beyond human mind's processing capability. So it's necessary to research on the high-efficiency intelligent methods that would fill up the gaps with innovation process and new methodologies. To

Illustration 1 Framework of basic-element theory [47]

certain degree, Extenics can help to understand the innovation process by formularized model.

3 Input Preparation for Extenics Based Innovation Model

In order to use information technology to efficiently support innovation, we have to prepare enough data and information as input for data mining, intelligent knowledge management and Extenics.

Extenics includes basic-element theory, extension set theory and extension logic [47]. The composition, basic concepts and related contents are showing in Illustration 1.

3.1 Collect Data Systematically Based on Basic-Element Theory

Innovation process needs data and knowledge, both explicit and tacit. There are two main sources for collecting data: Internal source, such as local data base of MIS, working tables or other files, External source, such as the Web, public data base, other companies with relationships et al. There are huge quantity of data and information. Besides business information systems, the World Wide Web has also become a common and huge information source. Billions of pages are publicly available, and are still growing dramatically. Choose the proper data to collect and process is difficult with limited resources.

Basic-element theory describes the matter (physical existence), event and relations as the basic elements for analysis on incompatible problems —“matter-element”, “event-element” and “relation-element”. It provides formalized languages that describe changes of matters and conversion of contradictions which provides a new formalized tool for expression of knowledge and information. Basic element is an ordered triad composed of the element name, the characteristics and its value, denoted by $R = (N, c, v)$ as matter-element, $I = (d, b, u)$ as event-element and relation-

element $Q = (s, a, w)$ [5]. As the matter-element $R = (N, c, v)$ is an ordered triad composed of the matter, its characteristics and measures, we can develop new concepts from the extensibilities of one of the three sub-elements in the triad [6].

Multiple characteristics are accompanied with multi-dimensional parametric matter-element, and can be expressed as [7]:

$$M(t) = \begin{bmatrix} O_m(t), & c_{m1}, & v_{m1}(t) \\ & c_{m2}, & v_{m2}(t) \\ & \vdots & \vdots \\ & c_{mn}, & v_{mn}(t) \end{bmatrix} = (O_m(t), C_m, V_m(t))$$

As to a given matter, it has corresponding measure value about any characteristic, which is unique at any moment.

Furthermore, characteristics of matters can be divided into materiality, systematicness, dynamism and antagonism, which are generally called matter's conjugation. According to matters' conjugation, a matter is consisted of the imaginary and real, the soft and hard, the latent and apparent, the negative and positive parts [47]. Accordingly, information for input of innovation also has four parts.

3.1.1 Information of Imaginary Part and Real Part

In terms of physical attribute information of matter, information for all matters is both of a physical part and a non-physical part. For example, the demand for a product's entity is its real part, while its brand and reputation are its non-physical part information.

3.1.2 Information of Soft Part and Hard Part

Considering a matter's structure in terms of the matter's systematic attribute, the matter's components is the hard part, the relations between the matters and its components is the soft part. "Three heads are better than one", three persons are hard parts. Their cooperation relationship is the soft part. Good soft part completely lead to good results.

The information of soft part has three types: (1) the relation between the matter's components; (2) relation between the matter and its subordinate matters and (3) relation between the matter and other matters.

3.1.3 Information of Latent Part and Apparent Part

In terms of a matter's dynamic property, any matter is changing continuously. Disease has its latent period; an egg can hatch into chicken at a certain temperature after a certain time. We need both latent information and apparent information for innovation.

The latent part of some matters may become apparent under certain conditions, for example, students in class currently will become teachers after ten years. There must be a criticality in the process of reciprocal transformation between latent parts and apparent parts.

Table 1 Information collection list on the element level

	Materiality		Systematicness		Dynamic		Antithetical	
	Real part	Imaginary part	Soft part	Hard part	Apparent part	Latent part	Positive part	Negative part
Matter-element	The real part of matter	Imaginary part of matter	Soft part of matter	Hard part of matter	Apparent part of matter	Latent part of matter	Positive part of matter	Negative part of matter
Event-element	The real part of event	Imaginary part of event	Soft part of event	Hard part of event	Apparent part of event	Latent part of event	Positive part of event	Negative part of event
Relation-element	The real part of relation	Imaginary part of relations	Soft part of relation	Hard part of relation	Apparent part of relation	Latent part of relation	Positive part of relation	Negative part of relation

3.1.4 Information of Negative Part and Positive Part

In terms of antithetic property of matters, all matters have two antithetic parts. The part producing the positive value in the measure of matter about certain characteristic is defined as the positive part for the characteristic, and the part producing the negative value in the measure of matter about a certain characteristic is defined as the negative part.

For example, In terms of profits, employees' welfare department, kindergarten, and publicity department, etc. have negative value of profits, but these parts will improve employees' job enthusiasm and promote company's brand, so they are the "advantageous" parts of the company.

The basic-element theory is a guide for collecting data and information systematically. The research of structure of matters guides us to build the information map by using matters' multi-attributes and interactive conjugations relations among them. Accordingly, we form a detailed information collecting list as showing in Table 1:

3.2 Goal-Oriented Data Collection Based on Extension Set Theory

All innovation events have their goals and the conditions. The purpose of data collection and processing is to design a pathway from current conditions to future target. Therefore, the information we collected should relative to the goal.

Extension set theory is a set theory that describes the changing recognition and classification accordingly. Extension set describes the variability of things, using the number in $(-\infty, +\infty)$ to describe the degree of how the thing owns certain property, and using an extensible field to describe the reciprocal transformation between the "positive" and "negative" of things. It can describe not only the reciprocal transformation between the positive and negative of things, but also the degree of how the thing owns a property.

Definition of Extension Set [47] Suppose U is universe of discourse, u is any one element in U , k is a mapping of U to the real field I , $T = (T_U, T_k, T_u)$ is given

Table 2 Information collection list from the view of the goal

	Goals	Conditions	Pathways
Field	Field of goal	Field of conditions	Field of pathway
Criteria	Criteria of goal	Criteria of conditions	Criteria of pathway
Element	Element of goal	Element of conditions	Element of pathway

transformation, we call

$$\tilde{E}(T) = \{(u, y, y') \mid u \in U, y = k(u) \in I; T_u u \in T_U U, y' = T_k k(T_u u) \in I\}$$

an extension set on the universe of discourse U , $y = k(u)$ the dependent function of $\tilde{E}(T)$, and $y' = T_k k(T_u u)$ the extension function of $\tilde{E}(T)$, wherein, T_U , T_k and T_u are transformations of respective universe of discourse U , dependent function k and element u .

if $T \neq e$, we define

$$E_+(T) = \{(u, y, y') \mid u \in U, y = k(u) \leq 0; T_u u \in T_U U, y' = T_k k(T_u u) > 0\}$$

as *positive extensible field* of $\tilde{E}(T)$; we define

$$E_-(T) = \{(u, y, y') \mid u \in U, y = k(u) \geq 0; T_u u \in T_U U, y' = T_k k(T_u u) < 0\}$$

as *negative extensible field* of $\tilde{E}(T)$; we define

$$E_+(T) = \{(u, y, y') \mid u \in U, y = k(u) > 0; T_u u \in T_U U, y' = T_k k(T_u u) > 0\}$$

as *positive stable field* of $\tilde{E}(T)$; we define

$$E_-(T) = \{(u, y, y') \mid u \in U, y = k(u) < 0; T_u u \in T_U U, y' = T_k k(T_u u) < 0\}$$

as *negative stable field* of $\tilde{E}(T)$; we define

$$J_0(T) = \{(u, y, y') \mid u \in U, T_u u \in T_U U, y' = T_k k(T_u u) = 0\}$$

as *extension boundary* of $\tilde{E}(T)$.

It can be seen from the above definition that there are three namely paths for the process of transformation between the “positive” and “negative”, field, criteria and element. Accordingly, the data and information we collect will include such 3 paths.

Goals and conditions can be matter, event, or relations between matters and events which can be represented with basic elements. So each cell in the Table 1 can be a basic element in next level of the information tree.

From Tables 1 and 2, we can get a systematic cube for collecting information for innovation as showing in Fig. 2.

3.3 Paths of Data Processing

The data preprocess chart is shown in Fig. 3 as following.

There are two main paths located at four levels. One path is to extract data from data base, or use web crawler to collect information from the Web, then transform and clean it into data mart, finally use data mining to discover primary knowledge. Another way is to collect documents and build an information cube by human, then save in base-element data base. Using extension transformation methods and data mining, we

Fig. 2 Extension information cube

Fig. 3 System struture of information collection and processing

will transform the base-elements into knowledge base, and cultivate new solutions by human-computer interaction (Fig. 4).

4 Framework and Process of Extension Innovation

4.1 Framework of Extenics based Innovation

The innovation method based on Extension Theory would take advantage of specific extension methods to generating new innovative ideas or solutions for the problem solving. The framework and its relevant steps are listed as following:

Step 1. Information and knowledge collection

Collect information and knowledge related to the innovation goal G and practical condition L from data base, expertise, tacit knowledge such as experience and the Web, according to the method presented in Sect. 3.1.

Step 2. Build base-element base for input

Describe and transform the information and knowledge as matter-elements, event-elements or relation-element. Then, we save them into data base as a base-element

Fig. 4 The framework model of extenics based innovation

tree as shown in Fig. 5. After this step, we could get a systematic cube of integrated information [21], according to the method presented in Sect. 3.2.

Step 3. From chaos to possible solutions

According to the goal, condition, or both goal and condition to search feasible propositions that would overcome the contradiction of the innovation problem. There are three main methods: Transformation, data mining and knowledge cultivating. By human-computer interactions, we get primary ideas and then operate them with scoring. Operators includes “*And*, *Or*, *Not* and *Xand*”.

AND means simultaneously implements two transformations. *OR* means select any one or more transformation in many transformations. *NOT* means recovers certain transformed objects to the original one. *Xand* means implements more than two transformations sequentially one after another. And the order can not be changed.

Apply basic transformation method, combination transformation method or transforming bridge method to transform the field, the elements or the criteria of the goals and conditions on matter-elements that are already explored by Step 2, the detailed description will be presented in Sect. 4.2.

Step 4. Testing and evaluation

We test and evaluate the possible solutions by superiority evaluation method. Operate the primary ideas generated through Step 2 to Step 3 with “*and*, *or*, *not*, *Xand*” and evaluate the solutions, resulting in trustworthy innovation proposals.

Suppose measuring indicators set $MI = \{MI_1, MI_2, \dots, MI_n\}$, $MI_i = (c_i, V_i)$, ($i = 1, 2, \dots, n$), and weight coefficient distribution is

$$\alpha = (\alpha_1, \alpha_2, \dots, \alpha_n)$$

According to the requirements of every measuring indicator, establish dependent functions. $K_1(x_1), K_2(x_2), \dots, K_n(x_n)$

A framework of Extension innovation model has been used in a famous company in China, a case study is presented as following in Sect. 5.

4.2 Directions of Innovation on Extenics

(1) From the view of descriptions, we can extend our ideas from object, character and its value, each object has many characters, marked as $1M : nC$, similarly, each character can has many values, such as color can be red, green, yellow or blue. We mark it as $1C : nV$.

Fig. 6 Explore the path from conditions to the goals

- (2) From the view of transformation path, we can extend our thinking from goals, conditions and both goal and conditions, which can be described as base-elements. Each path has many characters, values and objects.
- (3) Based on basic extension methods, there are five methods for the matter transformation, such as substitution, increasing, decreasing, expansion, contraction, decomposition, combination and duplication transformation.
- (4) From the view of transformation objects, we can transform the elements, such as matter, event or relationships. Or transform the criteria and field. For example, a sales man F is regarded as good in company A , but scored as bad after he changed to company B . F is element, the rules of *good* or *bad* is criteria, and A to B is field. Each change will lead to different results.

After four main transformations, we can get an information tree both for goals and conditions.

4.3 Explore the Path from Conditions to the Goals

Extension theory based knowledge cultivating process is shown in Fig. 6. The process of cultivating seed knowledge to innovation solutions has 6 main steps by a human-computer interactive method.

Step 1, Announce business problems and their condition-goal information with knowledge seed to all departments of the company on a sharing platform. The platform can be web site or management system or other BBS et al.

Step 2, Add information or knowledge related to the problems to the above platform. The information or knowledge should cover the real part and the imaginary part, the soft part and the hard part, the latent part and the apparent part, and the negative part and the positive part. In addition, correlation analysis and implication analysis are used to find the cause, the relation net et al. These will make sure that the problem is been considered systematically.

Table 3 Basic transformations of targets and conditions

Element transformation Methods	Goals			Conditions		
	Object	Attribute	Measure	Object	Attribute	Measure
Substitution						
Increase						
Decrease						
Expansion						
Contraction						
Decomposition						
Duplication						

Step 3, Connect information or knowledge by element name or its characters and measure. Clip redundant information or knowledge. A knowledge clustering will appear. This step can be implemented by software, which needs support of ontology base.

Step 4, Evaluate the clustered knowledge and select the feasible ones to make transformations. The transformations methods include replacement T_r , decomposition T_d , increasing or decreasing T_l , and expansion or contraction T_e , which are four basic transformations of matter-elements.

Step 5, Through above steps, we have formed a lot of knowledge trees, add human experience knowledge to connect them to be a whole knowledge tree.

Step 6, Judge if the tree can help make decisions and solve the problem. If not, we can collect much more information from it in next loop. If yes, store the main path into solve base and announce it to managers.

If a transformation T_W (or T_K or T_l) cannot solve an incompatibility problem, we can consider conductive transformations of these transformations.

The detailed transformation paths based on element transformation methods are listed in Table 3 as following.

4.4 Knowledge Mining Using Extension Transformation by Human

Based on extenics transformation methods [47], we use five basic transformations methods for information transformation by change matter's object, attribute or the value.

(a) Substitution transformation

As to basic-element $B_0(t) = (O(t), c, v(t))$, if there is certain transformation T that transforms $B_0(t)$ to $B(t) = (O(t), c, v(t))$, i.e. $TB_0(t) = B(t)$, then the transformation T is referred to as substitution transformation of basic-element $B_0(t)$.

(b) Increasing/decreasing transformation

Increasing transformation refers to increase certain attributes of the element. For example, as to matter-elements $M_0 = (\text{table } A_1, \text{height}, 0.8\text{m})$, $M = (\text{chair } A_2, \text{height}, 0.5\text{m})$, M is increasable matter-element of M_0 , we make $TM_0 = M_0 \oplus M = (\text{table } A_1 \oplus \text{chair } A_2, \text{height}, 1.3\text{m})$, then T is increasing transformation of M_0 .

Illustration 2 Extension methods for information transformation and processing [47]

Decreasing transformation refers to decrease certain attributes of the element. In the production process, the reduction of redundant action or work procedures belongs to the decreasing transformation of event-element, which can significantly improve production efficiency.

(c) Expansion/contraction transformation

Expansion transformation: Quantitative expansion transformation is multiple quantitative expansion of basic-element. As for matter-element, its quantitative expansion transformation will inevitably lead to expansion transformation of the matter. For example, the volume expansion of a balloon will inevitably lead to expansion of the balloon itself.

(d) Decomposition/Combination transformation

Decomposition transformation refers to divide one object or attributes into several pieces. On the contrary, Combination transformation refers to combine several objects or attributes into a whole one. For example, one action can be executed in several steps.

e) Duplication transformation

Duplication transformation refers to duplicate the basic-element to multiple basic-elements, such as photo-processing, copying, scanning, printing, disc carving, sound recording, video recording, the method of reuse, and reproduction of products, etc. This kind of transformation is extensively applied in the field of information, such as file copying and pasting. Other methods we use are listed in Illustration 2 as following.

4.5 Knowledge Mining Using Extension Transformation by Computer

Knowledge acquisition through data mining becomes one of the most important directions to support scientific decision making; however, the knowledge discovered from data mining may not work effectively because most of it only describes static knowledge, not how-to-do knowledge.

In data mining, researchers focus on how to explore algorithms to extract patterns that are non-trivial, implicit, previously unknown and potentially useful, but overlook the knowledge components of these patterns. The knowledge or hidden patterns discovered from data mining can be called “rough knowledge.” Such knowledge has to be examined at a “second-order” in order to derive the knowledge accepted by users or organizations. The new knowledge will be called “intelligent knowledge” and the management process of intelligent knowledge is called intelligent knowledge management. The purposes of proposing intelligent knowledge management are:

- (1) Define rough knowledge generated from data mining for the field of knowledge management explicitly as a special kind of knowledge.
- (2) The introduction of expertise, domain knowledge, user intentions and situational factors and the others into “second-order” treatment of rough knowledge.

Based on theory of Extension Set, knowledge from data mining can be mined in second level by transformation methods, such as substitution transformation, decomposition or combination transformation et al. for example, decision tree mined the explainable rules, but it is only static know-what knowledge, we still don’t know how to transfer class *bad* to class *good*. In order to improve such kind of situation, we focus on a new methodology for discovering actionable know-how knowledge based on decision tree rules and Extension set theory. It is useful to re-mine rules from data mining so as to obtain actionable knowledge for wise decision making. The transformation knowledge acquiring solution on decision tree rules are practically used to reduce customer churn (Li et al 2013).

5 Case Study

A company is one of the famous professional supplies company on children’s clothing integrating with design, development, production and sales in Beijing. It has a strong international background and good international market relationships. The company was founded in 1994. After 10 years development, the CEO feels hard to make a new big progress. In China children’s wear industry is from weak to strong and the competition is more and more seriously.

In 2007, the total sales of the company are 2.5422 billion Yuan, the effective output of 1,104.58 million Yuan, OE (Operating Expense) 83.081 million Yuan, NP (Net Profit) 27.376 million Yuan, and 139.68 million Yuan of inventory. The problems are shown in Fig. 7 where T denotes Throughput, the income from sales. The top 3 problems are:

1. An increase in sales but the effective output is not synchronized increase (for too much discounts and coupons);
2. The speed of OE (Operating Expense) increase is more quickly than that of the increase in throughput;
3. NP (Net Profit) decrease rapidly, and a rapid increase in inventory.

We collect information first on base-element theory. Matter information such as the company, products, customers, employees, suppliers, sellers, logistics and markets et

Fig. 7 Operation Analysis of the company from 2005–2007

al. is analysed by conjugation method. Event information includes planning, producing, marketing, transporting and on sale. Relation information includes relationships between suppliers, sellers, government and costumers et al. In the second step, we collect information and knowledge related to conditions and goals, and extend several paths by transformation method. From systematic information map, we find a lot of supposes and need more detailed information and rules.

Then, based on data warehouse, data mining and expert's analysis, we make about 20 information paths for management innovation on map of rules. Finally we draw the conclusion of why cash flow is negative and give out possible reasons as shown in Fig. 8.

By further analysis on why we should make plan in 1 year advance, the company get a lots of reasons. Accordingly, the following actions have been taken:

- (1) Make optimization of supply chain management, to achieve the company's central warehouse have enough goods stock and ensure that the inventory revolutions reach more than 6 times;
- (2) Make optimization of the distribution system, so that the stores have enough goods stock, and inventory of dealers or branch inventory is reduced to 50 % of the current level;
- (3) To improve the marketing system, increase the total number of stores to 2,000. The efficiency of the stores increased by 50 % per year from the current level;
- (4) Build the establishment of the company's diamond-type architecture, streamline management processes and establish the company's overall performance scoring system.

In 2011, after taken the actions, the company ranked No.1 in the similar childrens garment products field. The CEO won the entrepreneurs Award of 2010 contribution to promote the Chinese consumer economic growth. One of its brand gained the most

Fig. 8 Analysis on the basic reason of the problems

popular consumer brands and the “China’s top ten brand of children’s clothing” for three consecutive years.

6 Summary

Based on a literature review of existing innovation methods, the paper presents a framework of extension innovation model with concrete processes and a case study. The model integrates Extenics, data mining and knowledge management, and develops a framework for managing innovation and support team work. Firstly, we present a systematic method for collect information based on Extenics. By collecting knowledge or information from multi-resources among all departments in enterprises, this platform can build knowledge tree from every employee in varies forms. Secondly, we design a human-computer interaction model. Knowledge or information related to the problem can find relations by human-computer interaction method considering the new technology and the new innovation method based on Extenics Theory. This model combines qualitative analysis which would take advantage of personal intelligence after formalized expression of target innovation problems and quantitative analysis which follows a systematic flow based on accumulated knowledge or innovation patterns. Thirdly, we describe a innovation solution generate directions. It helps to solve management problems according to the extensibility of basic-element and will be applied in the innovation of management using data technology such as data mining and intelligent knowledge management. To a certain extent, it made the innovation black box a little transparent and scientific.

However, the framework model we presented in the paper is relatively simple, the knowledge emerge method and agent based system need to be integrated and simulate to enhance the extension innovation model [44,45]. Since the significant importance of big data, information and knowledge, deep research about combination of above methods with web information technology, data mining or knowledge management with Extenics would be further topic. How to update ontology automatically and simulate the knowledge innovation process by intelligent agent is a challenge problem. We define it as intelligent innovation in the era of big data which will be our future research

directions. Moreover, fuzzy set, complexity science and social agent technology will be utilized to improve the innovation model.

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