A Method of Emergency Management based on Knowledge Element Theory

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***Abstract*—According to the current situation in emergency management of the low utilization and slow search for emergency document knowledge result to the efficiency in making decisions. This paper aims to solve the problem of difficult in searching needed knowledge in emergency management. From the perspective of knowledge system engineering, this paper conducts an in-depth study on knowledge-mined model of emergency documents and offers an alternative for decision-makers to locate and use emergency document knowledge more quickly and efficiently by emergency document knowledge modeling based on knowledge element. This modeling process includes the analysis of physical and logical structure, the navigation link based on knowledge element and the knowledge reasoning and retrieval. The physical analysis aims to extract the metadata and structure the documents; the logical analysis intends to classify the knowledge element into three types, namely the event-based knowledge element, the subject-based knowledge element, and the task-based knowledge element; and the navigation link targets at establishing the link between the knowledge and the structured document. At last, we propose a prototype of emergency knowledge decision supporting system for verifying the validity of its application, of which the results indicate that the modeling approach is both practical and effective.**

***Index Terms*—Emergency management; emergency decision making; structured document; knowledge element**

I. INTRODUCTION

In recent years, the increasingly unexpected incidents such as the Wenchuan Earthquak in Sichuan in 2008 and the outbreak of H1N1 flu in 2009 set forth a new challenge to the emergency management. To deal with the emergency case, only fast and accurate access to the right knowledge can our government takes further measures. Consequently, numerous emergency documents have been developed from different perspective. Informative these documents are, they are poorly-structured. For what the decision-makers really need is the knowledge in the document, not the document itself. The fact that the needed knowledge may be imbedded in different parts of the same document or in different documents slows down the searching process and thus leads to the poor use of this knowledge, which in turn impedes the rapid and effective decision making.

Different departments develop a large number of emergency documents, these documents contains a great amount of information, but not well structured. However, what the decision-makers really need is the knowledge in the documentation, not the document itself, they come from different documents or different parts of the same document. The previous problems led to the not efficiency of finding and using knowledge, this caused difficulties in the emergency decision-making. Current studies on emergency management information system mainly focus on the acceleration of the information communication and transmission of decision-making instructions.

The emergency management of unexpected public events has become the focus of study. Mei-Po Kwan [1] proposed the Intelligent Crisis Response System (GIERS) based on three-dimensional GIS to realize rapid response from multi-level structure to terrorist attacks. Paper [2] by changing the traditional level-by-level reporting system, established a web-based emergency tracking and a decision-making system. Paper [3] established an emergency system of public security field based on GIS. Yang Yang [4], set forth a genetic algorithm using fuzzy decision tree to select parameters. While these emergency decision making systems, to a certain extent, offer the knowledge needed for emergency decision making, they were made within the framework of traditional decision-making support system, with the knowledge in the knowledge base having little or nothing to do with the specific emergency case, and thus do not realize knowledge management in real sense.

This paper, from the perspective of knowledge system engineering, conducts an in-depth study on the fine-grained knowledge-mining model for emergency documents. It offers an alternative for decision-makers to locate and use emergency document knowledge more quickly and efficiently by integrating all knowledge from various emergency documents into knowledge pool which can dynamically generate the knowledge needed for decision making on a specific emergency case.

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II. Framework of Emergency Document Structure Modeling Based Knowledge Element

With the development of knowledge economy, what people want to access is not the document itself, it is the inside knowledge that people really want to get. By promoting of the development of need, the control unit of knowledge will be deepen into the document data, once realize this change, once achieved this transformation, the "knowledge element" contained in document will link with the relate information. This will have great knowledge of the value-added, and thus promote the efficiency of using of knowledge.

Definition 1 knowledge element: we take each document as relatively independent knowledge elements which are arranged in certain logical relationship. Each element is the smallest structure to express the content of knowledge, known as the "knowledge element".

Definition 2 feature vectors: feature vectors, also called search terms, represent the nature of the emergency document knowledge retrieved. For example, the key words retrieval of emergency knowledge forms a vector D (t_1, t_2, ... , t_n), of which 'n' represents the number of items retrieved.

Definition 3 weight (W_k) of the feature vector: feature vector weight refers to the amount of emergency knowledge that can be represented by the term t_n. It reflects the importance of feature items in emergency knowledge information. The feature vectors of emergency document D can be expressed as $D_i = (W_{i1}, W_{i2}, ..., W_{in})$, of which $w_1, w_2, ..., w_n$ represent the weight of document information D (t_1, t_2, ..., t_n).

The general idea of emergency document structure modeling is as follows: take each document as "knowledge elements" which can be extracted for storage and outputted and formed, based on user's needs, new knowledge units when responding to inquiries. Specifically, this process can be divided into the following four steps such as shown in Figure 1.

Step 1: Analyze the physical structure of a document and then separate the knowledge elements out of the document. Extract the features items from the document based on Salton's vector space model, and form the feature vectors, namely to express document D as D(t_1, t_2, ..., t_n), of which t_i is the feature items, $1 \leq i \leq n$. M documents in the collections document constitute M * N feature matrix. Each document is physically broken down into metadata or structured documents to be stored.

Step 2: Analyze the logical structure of the document and identify the corresponding relationship between the needed knowledge and the paragraph subject (paraSubject). In this step, the knowledge of emergency document is divided into three categories, namely the event-based, task-based, subject-based. In accordance with these three different types, extract the knowledge elements from subject paragraphs to build the knowledge element index vector E (t_1, t_2, ..., t_n). Organize data with two-dimensional relational table, and then store them, forming a knowledge base.

Step 3, build navigation to guide knowledge element so as to establish links among the knowledge elements, and links between the knowledge elements and the documents.

Finally, user's query is also represented as a group of space vector Q (q_1, q_2, ..., q_n), by calculating the similarity between user's query request and documentation Sim(D_i, Q_j), knowledge element Sim (E_i, Q_j) to deliver the document and knowledge retrieval and reasoning [5] [6] [7].

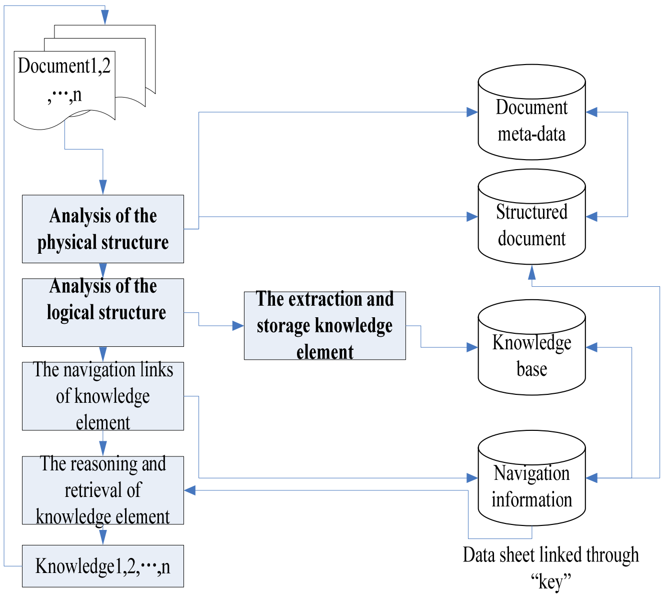

Figure1. The Framework of Emergency Document Structure Modeling Based on Knowledge Element

III. Analysis of the Physical Structure of the Document

The document structure includes the physical structure and the logical structure. The physical structure is the attribute that data actually stored in computer. Through the analysis of the physical structure of the emergency documents, we get some independently structured information such as institutions, release date, document title, the nature of document, etc, which can physically separate the document itself from described information. We put these structured information as a document meta-data and store them in a relational database while the documents storing in the file system. The documents and the meta-data can be associated by address properties.

A. Metadata Extraction

Metadata is a structured data about information or data which provides a structured description of information resources. Meta-data field represents the nature of document retrieval and it can be regarded as a feature item t of the document space vector model. An emergency document information are made up of by independent feature items t_1, t_2, ...,t_n, with 'n' being the number of feature items. M copies of documents constitute a collection D=d{d_1,d_2,······, d_m}, which be expressed as an $m \times n$ document information matrix A by n-characteristic items t1, t2, ..., t_n. The feature vector matrix of A is

$$A' = (W_{ij})m \times n = \begin{bmatrix} W_{11} & W_{12} & \dots & W_{1n} \\ W_{21} & W_{22} & \dots & W_{2n} \\ \dots & \dots & \dots & \dots \\ W_{m1} & W_{m2} & \dots & W_{mn} \end{bmatrix},$$

of which row vector for the document information vector, column vector for the search term vector. w_{ij} is the weight of the document i in retrieving item j. Since the capacity of the emergency document D represented by each feature item t_i is different, the weight is different too.

Establish document meta-data table {File_ID，F_Title，F_Auth，F_Pdata，F_Attrib，F_Class，F_Grade，F_Dsc，F_URL} to store document information matrix. The following is a description of the feature items:

File_ID represents the document number which is the main attribute of the metadata table; F_Title, F_Auth, F_Pdate: represent the document title, document author and release date respectively. F Attrib represents the nature of the document, its value = ('contingency plans' | 'laws and regulations,' | 'principles guide' | 'Emergency Cases' | 'others'). F_Class refers to event classification which stores event type number and corresponds with the event type table. F_Grade refers to the event class which can be divided into national, provincial and municipal level. F_Dsc is a description of document content which will give the users the main ideas about the content of the document. F_URL specifies the address of the document stored on the server.

For example, the two documents "General Plan for Rapid Response to Public Emergencies of the Country" and "Destructive Earthquake Emergency Regulations", the metadata will be stored as shown in Table I.

TABLE I. FEXAMPLES OF EMERGENCY DOCUMENT META-DATA STORAGE

File_ID	F_Title	F_Auth	F_Pdate	F_Attrib	F_Type	F_Grade	F_URL
0000	National emergency event	State council	2006-1-8	emergency plan	0	National level	127.0.01/file/0000.doc
2222	Destructive earthquake	State council	1995-2-11	Laws and regulations	Null	National level	127.0.0.1/file/2222.doc
……	……	……	……	……	……	……	……

B. Document Structuring

Obviously the knowledge needed by emergency decision-makers centers around certain subject. Since this knowledge may come from a part of an article rather than the entire document, we use the structural information inherent in the document to improve the matching accuracy and make available to decision-makers the solutions more quickly and conveniently. The structured documents stored in the database can match the targeted queries request, and return a document of interest to the backbone, or the content under the sub-title. Most of the emergency plans already have certain structural characteristics themselves and thus it is not difficult to identify their physical structure and logical structures.

In order to better store and representing such documents as emergency plans, we design the structured document table Str Text to explain the naming, the meaning of the document as well as the idea of tiered storage. In the Table II, Node_ID is the node number representing the node in the article (the title or paragraph). The number consists of 12 digit numbers, of which the first 4 number is the document number and every two of the remaining eight numbers express one level, making a total of four levels of content altogether. For example, the number 01 01 01 00 can be used to represent the first three levels of the document contents. N_Level is the node depth, for example, the value of the subtitle in this field is 2. N_FathID is the node number on the upper layer. N_Attr is the document properties. 't' indicates that the node is the title, 'p' indicates that the nodes in the body of the paragraph. File_ID is the document number, which links structured documents together with document meta-data. It makes the main attributes together with Node_ID. N_Content is a node representing the title or paragraph of the document.

The following are examples concerning the storage of structured document. The contents in the document box are from the "General Plan for Rapid Response to Public Emergencies of the Country". The document can be divided into titles of different levels. We take the first level title "General" as 1, the rest parts will add 1 in N level value as long as they are subordinate to it in content; the value of N_Level remains unchanged if they are in coordinative relationship. Table II is an attempt to offer a solution to store document in the structured method.

TABLE II. EXAMPLE OF THE STORAGE OF STRUCTURED EMERGENCY DOCUMENTS

Node_ID	N_Level	N_FathID	N_Attr	File_ID	N_Content
01000000	1	0001	t	0000	General Rules
01010000	2	01000000	t	0000	Purpose
01010100	3	01010000	p	0000	Enhance the government'a ability to ensure public safety and deal with the pubic emergencies⋯
01020000	2	01000000	t	0000	basis

IV. Document Logical Structure Analysis

A. *Features of Paragraph Subject*

After careful study of various types of national, provincial emergency response plans, we found that emergency plans manifest certain features in both form and subjects. As far as the form is concerned, a complete emergency plan typically includes the following six components: general principles, organizational system, procedures, safeguard measures, supplementary provisions and appendices. Paragraphs, on the other hand, being the smallest independent unit embodying the form of the document, fall into the following three categories, corresponding to the document form.

The first category defines and explains the concepts. The word ‘what’ is used to represent the interrogative what, ‘VL’ represents "is", ‘NI’ represents noun phrases such as terminology, concepts, names, etc. Thus the feature of the ParaSubject can be expressed as: ParaSubject = NI + VL + What.

The second category describes the process of settling down an incident, with subject matter being who. Thus the word ‘who’ is used to represent the interrogative who, ‘VL’ represents the verb "is" while ‘Sub’ represents the parties involved in emergency response. Thus we will have: ParaSubject = Sub + VL + Who.

The third category describes the task of different parties in the process of commanding and coordinating the efforts in response to emergency cases. With the word ‘Sub’ meaning "subject", ‘When’ the interrogative when, ‘V’ the action "how to deal with", ‘NEM’ the unexpected event to be dealt with, the feature of the ParaSubject can be denoted as: ParaSubject = Sub + When + V + NEM.

The relationship between the features of three types of ParaSubject and the various parts of an emergency plan is shown in Figure 2.

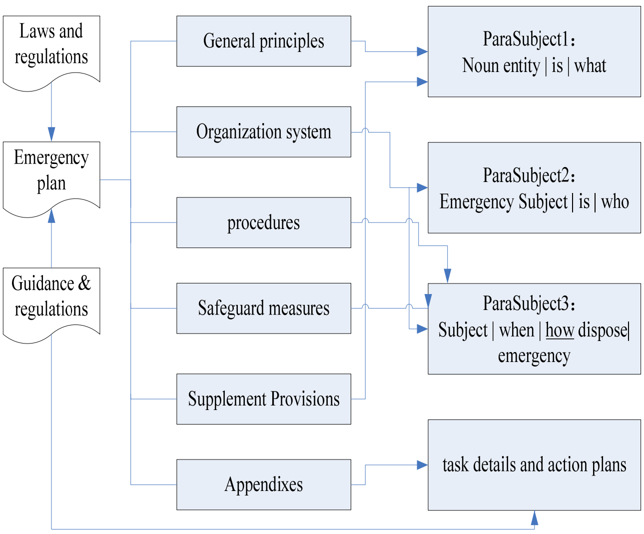

Figure2. The relationship between the ParaSubject features and form of a document

B. *Classification of Knowledge Element*

Knowledge element is the smallest unit to express knowledge. A paragraph is the structure to express certain subject. Since any kind of knowledge is embedded in paragraph, there exists a link between paragraph and knowledge element. If the subject of the paragraph is different, the knowledge contained in it is also different too. Sometimes certain types of knowledge may come from a number of discrete paragraphs, and each paragraph contains one or more knowledge element.

(1) event-based knowledge element corresponds to the first category of ParaSubject, i.e.the paraSubject that plays the role of interpreting and describing the noun phrase, aiming to resolve the question of "About What".

(2) subject-based knowledge element corresponds to the second category of Parsubject, namely the paraSubject that describes the parties involved, showing which department is responsible for the what activities. It addresses such problems as "About Who".

(3) task-based knowledge element corresponds to the third category of ParaSubject, namely the ParaSubject being abstracted into terms like "emergency dealing entity / when / how to deal with / unexpected problems". It is the key part of emergency plans, addressing such problems as "About Who", " About When ", " About How " problem.

C. *Extraction of Knowledge Element*

As we know, knowledge element is the smallest unit to express knowledge, and paragraph is a structure to express certain themes. Any kind of knowledge actually relies on the logic paragraph subject. Therefore there exists a corresponding relation between paragraphs and knowledge element. A different subject of the paragraph includes different knowledge types. Some types of knowledge may come from several discontinuous paragraphs, at the same time, each paragraph corresponds to one or more knowledge element. Because of the correspondence, we can extract the subject of the corresponding knowledge element according to the theme features of paragraph.

(1) event-based knowledge element

The first paragraph subject is characterized in the interpretation and description of noun phrases, resolved "About What" problem, the event type knowledge element corresponding to it, as shown in Figure 3.

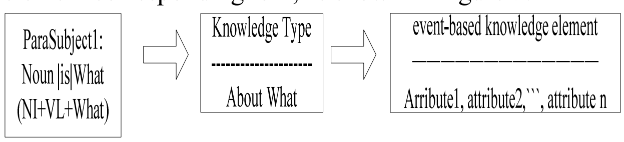

Figure3. The correspondence between event-based knowledge element and paragraph subject

(2) subject-based knowledge element

The second paragraph subject describes the various types of subject that emergency events related, tell us which department is responsible for related work, solved the "About Who" problem corresponding with the subject-based knowledge element, as shown in Figure 4.

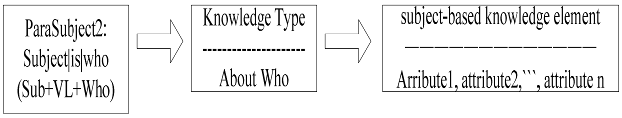

Figure4. The correspondence between event-based knowledge element and paragraph subject

(3) task-based knowledge element

The third paragraph subject can be abstracted as the form as "emergency subject / when / how to dispose / unexpected problems", which is a key part of contingency plans. It addressed the "AboutWho", "AboutWhen", "About How" issues, and correspondence to task-based knowledge element. Because a task has executor, the execution time, manner, mission objectives and other factors, and these factors can be obtained from the third paragraph subject, as shown in Figure 5.

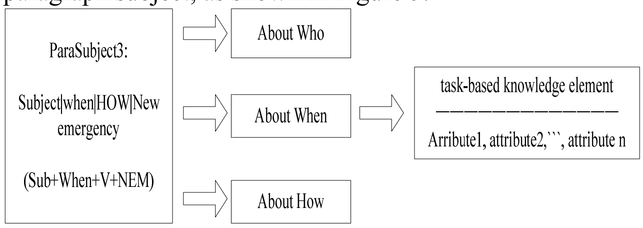

Figure5. The correspondence between event-based knowledge element and paragraph subject

According to the common features of three types of knowledge, we try to build a multi-group KE {name, attrib, guide} to express knowledge element, i.e. knowledge element = {number, name, attributes, navigation}. Among them, name is the subject of knowledge studied; attribute is the characteristics that knowledge element owned, with different types of knowledge element having different attributes structure; navigation shows the connection among the knowledge elements and between the knowledge element and the emergency plan document.

Here is the solution to the problem of presenting the name of a knowledge element in computer. Since the knowledge elements are stored with database technology, in order to, we need to add such distinguishing field as 'knowledge element Number ' to make the data more in line with the organizational form of documents ; other fields should be added as needed. Here the entity table-KE (K_ID, K_Name, K_Type, K_Dsc) is employed to represent knowledge elements, of which K_ID is the knowledge element Number and its major properties; K_Name is the name of knowledge element, brief introducing the subject of study of the knowledge element; K_Type is the category of the knowledge element including the "event-based", "subject-based" or "task-based."; K_Des is a further description of knowledge element. We take the "Proposals in Response to National Environmental Emergency" for example, to show the extraction of the knowledge element, as shown in Table III.

TABLE III. EXAMPLE OF THE KNOWLEDGE ELEMENT TABLE

K_ID	K_Name	K_Type	K_Dec
K004	Classification and grade of the event	Event-based	Description of environmental emergency
K005	Coordinating institutions	Subject-based	Identification of coordinating bodies and their responsibilities
……	……	……	……

V. KNOWLEDGE ELEMENT NAVIGATION LINKS

Similar to the knowledge element representation, the navigation of knowledge element can also be described in two-dimensional relation table. We build the knowledge navigation table KNav {K_ID, NavID, NavLink, NavDes}, of which K_ID is the foreign key of the relationship, associating with the knowledge element tables; NavID is the navigation link number, used as the main attributes of the relationship; NavLink corresponds to the node number of the structured document table Node_ID, aiming to establish the links of the knowledge element and structured document, and to establish the links to document meta-data, which forms emergency knowledge chain. For example, we extract the definition of environmental emergencies from the "Proposals in Response to National Environmental Emergency" and put it into the knowledge element table as shown in Table IV.

TABLE IV. EXAMPLE OF THE KNOWLEDGE ELEMENT NAVIGATION LINK TABLE

K_ID	NavID	NavLink	NavDes
K76	N_76	120007010200	Definition the events.

VI. RETRIEVAL BASED ON VECTOR SPACE MODEL

Vector Space Model (VSM) is a statistical model on document expression which is proposed by Salton and el. The model takes feature items as the coordinates of the document expression. The document is expressed as a point of multidimensional space in the form of a document vector, with the feature item weighed in some way. Thus a text can be represented by a feature vector in space [8]. For the case of emergency document, for the emergency document collections D = $\{d_1, d_2, ..., d_m\}$, or knowledge element set E = $\{e_1, e_2, ..., e_m\}$, can be expressed as a $m \times n$ c feature vector matrix $A' = W_{ij}$ by 'n' feature items. 'n' defines a n dimensional document information space, each document has its own feature vector; and the same time, the query of policy-makers in this vector space can also be expressed as a vector, so the similarity of query vector can be transformed into the calculation of the angle between two vectors. The smaller of the angle, the higher similarity is, and more front in the ordering.

Detailed algorithm is as follows:

Function: generate the result based on the user's input request.

Input: user query $Q_j(q_1, q_2, ..., q_n)$, of which the key words q_i correspond to retrieve items t_i.

Output: sorted collection of documents or knowledge $D(d_1, d_2, ..., d_k)$.

Process:

(1) based on the weight of retrieve item (suppose the weight of $t_1, t_2, ..., t_n$ are $w_1, w_2, ..., w_n$, and $w_1 + w_2 + ... + w_n = 1$ respectively), transform the user query into query vector;

(2) the calculation of feature vector of the documents and knowledge element: If d_i was hit by the keywords q_k in the search options, then the feature vector of d_i values w_k on W_{ik};

(3) repeat step (2) until all retrieval items have been done. Get the vector representation of the emergency document or knowledge element: $D_i = (W_{i1}, W_{i2}, ..., W_{in})$;

(4) use the following formula to calculate the angle cosine value of the user query vector Q_j and the similarity of document vector D_i (or knowledge element vector);

$$Sim(D_i, Q_j) = \frac{\sum_{k=1}^{n} W_{ik} \times W_{jk}}{\sqrt{(\sum_{k=1}^{n} W_{ik}^2) \times (\sum_{k=1}^{n} W_{jk}^2)}}.$$

(5) order the search results on the basis of similarity degree, and make judgment on a given threshold value: output those meeting the requirements, screening out the rest;

(6) the end.

VII. PROTOTYPE

Based on the Visual Studio.net 2005 technologies and concepts of emergency document structuring modeling process, the Enterprise Information and Knowledge Management Lab of South China University of Technology has developed a prototype on support system for decision-making knowledge in response to emergency management, with document retrieval and knowledge element retrieval as its major purposes. The following two pictures are the search interfaces of proposals in response to emergencies as well as knowledge elements.

In the knowledge element interface shown in Figure 5, select "event-type knowledge" in the drop-down menu, enter "earthquake" in the event name in textbox, and then you can have all search results. The results are drawn from other emergency proposals based on the event type and other conditions of the user and are ready for use. The knowledge names with a hyperlink are shown in the interfaces, and the details of the knowledge element can be acquired by clicking on these names (kedetail.asp).

The test-run of the Prototype system proves that the system can quickly provide the necessary knowledge for decision makers in front of emergency cases. It can, to a certain extent, meet their needs for knowledge while helping them to save valuable time. It works well in the running speed and performance and has solved the problem of explicit knowledge retrieval and application.

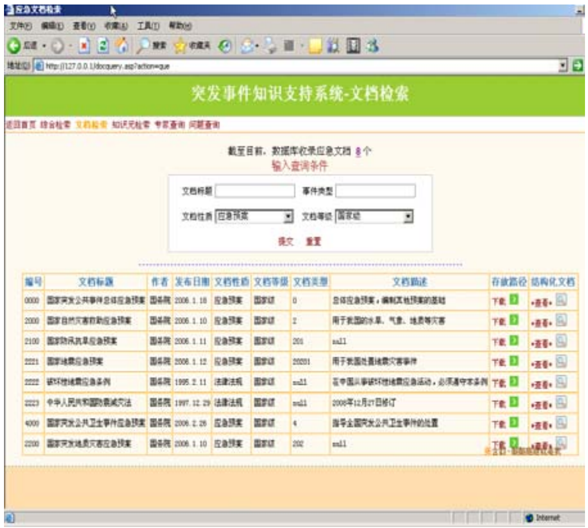

Figure6. Emergency Proposal Retrieval

Figure7. Knowledge element retrieval

VIII. CONCLUSIONS

Currently the emergency management of unexpected public events has become the focus of study. This paper, on the basis of the knowledge element theories and detailed study on the features of various emergency documents, sets forth an emergency document structuring model to deal with the emergencies.

Our method from the knowledge engineering point of view, combined with knowledge of meta-theoretical modeling of knowledge among emergency documents and make in-depth discussions on the fine-grained mining emergency document model of knowledge. Integrate all the emergency documentation of knowledge into knowledge base, and can dynamically generate the necessary knowledge, and provides a new way for decision-makers quickly and effectively use knowledge of emergency document. This modeling process includes the analysis of physical and logical structure, the navigation link based on knowledge element and the knowledge reasoning and retrieval. The physical analysis aims to extract the metadata and structure the documents; the logical analysis intends to classify the knowledge element into three types, namely the event-based knowledge element, the subject-based knowledge element, and the task-based knowledge element; and the navigation link targets at establishing the link between the knowledge and the structured document.

The model can be described as a four-step process. First, extract the meta-data and structure the document by conducting the physical structure analysis; second, divide the meta-data into the event-based knowledge, subject-based knowledge element and task-based knowledge element and work out a way to extract knowledge element; third, establish the links between knowledge and structured document by knowledge element navigations, and forth, have knowledge reasoned and retrieved. The paper also explores the fine-grained knowledge mining process of emergency documents.

At last, we developed a prototype on support system for decision-making knowledge in response to emergency management. The results of the laboratory tests show that our method of modeling is both practical and effective. After structuring the emergency documents, we can generate the corresponding knowledge elements or documents according to key words retrieved by the decision makes. These knowledge elements or documents will be more useful to decision makers if they can be integrated into a complete proposal, which deserve further study in the future.

Our future work will be integrate the knowledge element and the document into a comprehensive contingency plans, it will be more useful to emergency response decision makers. So for, it also needs to be done further study on how to integrate the retrieved knowledge element and documents into a complete contingency plan.

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