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Ontology Construction for Hazardous Chemical Fire Emergency Response

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Abstract. China's chemical industry has developed rapidly, but chemical production safety is still in the primary stage, hazardous chemical fire occurs frequently. The ontology model Hazardous Chemicals Fire Emergency Reaction Ontology (HC-FERO) is constructed on the basis of the knowledge domain and the breadth and depth of ontology. First, ire emergency response upper ontology is constructed with the help of domain experts. Then, a quintuple is established from the aspects of Fire response sequence, response rules, fire extinguishing principle, etc, then we choose protege to generate the hazardous chemical fire emergency ontology. At last, we select the qualitative evaluation to evaluate HC-FERO.

Keywords. Hazardous chemical fire, fire response sequence, response rule, the emergency

1. Introduction

With the rapid development of national economy and the continuous progress of science and technology, the production scale and savings of hazardous chemicals in China continue to increase [1]. As a result, accidents of hazardous chemical production rose. Compared with developed countries, China's chemical production safety refinement, intelligence are all in the primary stage. These lead to the chemical industry prone to production safety hazards and then evolved into hazardous chemical fire.

In recent years, large-scale chemical disasters have occurred in various cities of China with heavy losses and huge impacts. At the same time, there are shortcomings and weaknesses in the working system of the national comprehensive fire rescue team to deal with hazardous chemical disaster accidents, such as imperfect knowledge structure and weak basic work. There is a gap between the professional fire rescue team and the requirements of completing complex and heavy chemical disaster accident handling tasks [2].

By extracting prominent features of chemical disasters and taking some cases of hazardous chemical fires recorded in literature as samples, we selected the ontology description to build a model for the response stage which is used hazardous chemical fires [3][4].

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2. Background

Ontology model can standardize unified concepts and terms in a certain field and promote the integration and sharing of knowledge and concepts [5][6]. At present, most models constructed are integrated ontology models for emergency management research, as well as some models for fire emergency management research[7][8]. These scholars above constructed ontology models of various levels and categories. However, the domain scope of these ontology models is too broad and the granularity of concept is not fine enough. More importantly, there is no ontology for the field of fire emergency response, not to mention the ontology model for the field of hazardous chemical fire emergency response haven't studied yet.

Therefore, we intends to use information extraction technology to extract the knowledge in the text of hazardous chemical fire automatically, refine and improve the ontology model established by predecessors, then construct an ontology model for hazardous chemical fire [9][10].

3. Model Construct of HC-FERO

3.1. Upper ontology of HC-FERO

The upper ontology conceptual structure mainly complies with FE-SUMO.

3.2. Capture of ontology knowledge for HC-FERO

A total of 305 professional fire fighting documents were selected from Pull real fire files from teams in multiple areas such as Shanxi, Liaoning, Heilongjiang, Jiangsu and other provinces. Based on the analysis of serving firefighters and the guidance of experts in the field, the basic knowledge is tested.

Based on these information given above, we adopts the bottom-up approach to construct the HC-FERO by semi-intelligent method [11][12]. The following definition of The Hazaedous Chemical Fire Emergency Response Ontology (HC-FERO) is given

HC-FERO-Ontology = <HC-FERO-Concepts, HC-FERO-Relations, HC-FERO-Functions, HC-FERO-Axioms, HC-FERO-Instances> [13]

3.2.1 HC-FERO-Concepts

In the premise of the core concepts in FEO [8], HC-FERO Some key concepts in FEO have been adjusted and the newly emerging ones have been added on top of them as follows:

Hazardous chemical substance. It's a subclass of matter with nine subcategories such as explosives, flammable liquid, flammable solid, pyrophoric material, wet flammable material, oxidizer and organic peroxide, drugs, radioactive material and corrosive material[2] .

[2] According to the "Classification and Marks of Commonly used Hazardous Chemicals", issued by the State Bureau of Technical Supervision in 1992.

Burning. It's a subclass of procedures. It has four subcategories such as diffusion combustion, surface combustion, evaporation combustion and decomposition combustion.

National comprehensive fire rescue team. It's a subcategory of fire emergency organization. The structure of the national comprehensive fire rescue team consists of fire rescue (forest fire) bureau, corps (mobile detachment), detachment, brigade and fire rescue station (detachment).

Fire emergency response process. It has four subcategories such as fire response, police response, on-site implementation and recall.

Fire extinguishing agent: water, class A foam, class B foam, gas extinguishing agent, liquid extinguishing agent.

Fire extinguishing method: refers to the fire extinguishing method, which is a subclass of process, generally including cooling fire extinguishing, suffocation fire extinguishing, isolation fire extinguishing and chemical suppression fire extinguishing.

Figure 1 illustrates some of the key concepts of HC-FERO.

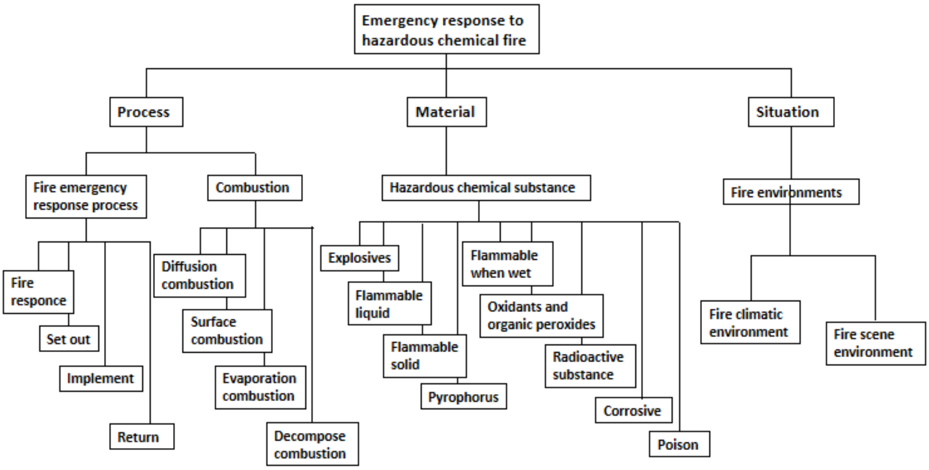

Figure 1. Ontology structure diagram for HC-FERO

3.2.2 HC-FERO-Relations

We can ascertain the relations of HC-FERO concept set based on the thesaurus and algorithm, which named HC-FERO-Relations. In the individual of HC-FERO-Relations, if $R_x \in$ HC-FERO-Relations, then

$$R_x(C_0, C_1), \text{ where } C_0, C_1 \in \text{HC-FERO-Concepts}.$$

Under the premise of FEO-Relation, the HC-FERO-Relations are as follows:

Having class relationships have been added to such relation as identity relationship.

Action relations have been added to such relations as clean and disinfect, command, internal attack, alert, search and rescue, reconnaissance, reporting and reinforcement. Table 1 shows more details.

Table 1. HC-FERO-Relations

Relation category	Relation name	Instructions
Inherited relation	Paternal succession	Consistent with FEO-Relation
	Whole and part	Consistent with FEO-Relation
	Attribute	Consistent with FEO-Relation
	Instance	Consistent with FEO-Relation
Have relation	Time	Consistent with FEO-Relation
	Space	Consistent with FEO-Relation
	Level	Consistent with FEO-Relation
	Type	Consistent with FEO-Relation
	Process	Consistent with FEO-Relation
	Identity	Describe the relationship between the firefighting unit and the firefighting role.
Act relation	Clean and disinfect	Describe the separation relationship between fire emergency responders and hazardous chemicals.
	Command	Describe the operational relationship between the national Integrated Fire rescue team and fire emergency responders.
	report	Describe the relationship between fire emergency responders and the national Integrated Fire rescue team.
	Inside fire attack	Describe the relationship between fire emergency responders and the combustion environment.
	rescue	Describe the relationship between non-fire emergency responders and trapped persons.
	reinforce	Describe the relationship between the national Integrated Fire rescue teams.
	Block	Describe the relationship between fire emergency responders and incendiary objects.
	Control	Describe the relationship between fire emergency responders and combustion outcomes.
	Encircle and suppress	Describe the changing relationship between fire emergency responders and incendiary objects.
	Operate	Describe the use relationship between fire emergency responders and fire response equipment.
	Forcible entry	Describe the changing relationship between fire emergency responders and objects.
	Insulate	Describe the interdiction relationship between hazardous chemicals and incendiary substances.
	Wear	Describe the relationship between fire emergency responders and personal protective equipment.
	Combat	Describe the relationship between fire emergency responders and incendiary objects.
	Guard against	Describe the isolation relationship between non-fire emergency responders and burning objects.

3.2.3 HC-FERO-Functions

If f_s is an individual of HC-FERO-Functions, then the first r elements of HC-FERO confirm the r+1 element uniquely and directly. Conversion into a formula expression is, $f_s \in$ HC-FERO-Functions, then

f_s (C_0, C_1,... , C_r) = C_{r+1}, where C_0, C_1...... , C_r, C_{r+1} ∈ HC-FERO-Concepts.

The combustion results and combustible conditions can be determined.

f_1 ($C_{\text{hazardous chemical}}$, $C_{\text{combustible condition}}$) = $C_{\text{combustion result}}$,

where $C_{\text{hazardous chemical}}$, $C_{\text{combustible condition}}$, $C_{\text{combustion result}}$ ∈ HC-FERO-Concepts .

The type of combustion, fire extinguishing method and fire extinguishing agent can be determined.

f_2 ($C_{\text{hazardous chemical}}$) = $C_{\text{combustion form}}$,

where $C_{\text{hazardous chemical}}$, $C_{\text{combustion form}}$ ∈ HC-FERO-Concepts .

f_3 ($C_{\text{hazardous chemical}}$) = $C_{\text{fire-extinguishing method}}$,

where $C_{\text{hazardous chemical}}$, $C_{\text{fire-extinguishing method}}$ ∈ HC-FERO-Concepts.

The reaction mode of hazardous chemicals can be determined according to the type of hazardous chemicals and the fire environment.

f_4 ($C_{\text{hazardous chemical}}$, $C_{\text{fire environment}}$) = $C_{\text{hazardous chemical reaction method}}$,

where $C_{\text{hazardous chemical}}$, $C_{\text{fire environment}}$, $C_{\text{hazardous chemical reaction mode}}$ ∈ HC-FERO-Concepts .

Fire extinguishing agent can be determined according to the reaction mode of hazardous chemicals.

f_5 ($C_{\text{hazardous chemical reaction method}}$) = $C_{\text{extinguishing agent}}$,

where $C_{\text{hazardous chemical reaction method}}$, $C_{\text{extinguishing agent}}$ ∈ HC-FERO-Concepts .

3.2.4 HC-FERO-Axioms

As the proposition in the model, axioms are the premise of reasoning. The form is described as HC-FERO-Axioms ={A}.

3.2.5 HC-FERO-Instances

HC-FERO-Instances are defined as a collection of instances representing a number of concepts in the HCFERO, which can be formalized as

HC-FERO-Instances = {I | C (I) ∈ HC-FERO-Concepts ∪ HC-FERO-Relations}

Here are some examples:

Water, class A foam, class B foam, gas extinguishing agent and liquid extinguishing agent are examples of extinguishing agents.

Cooling fire fighting, asphyxiation fire fighting, isolation fire fighting and chemical suppression fire fighting are examples of fire fighting.

3.3. HC-FERO ontology knowledge extraction

Protege 5.5.0 was selected as the ontology construction tool of this study to build the emergency ontology of hazardous chemical fire. The language that describes these ontologies is OWL. Figure 2 shows the relationships between some of the concepts of the constructed ontology.

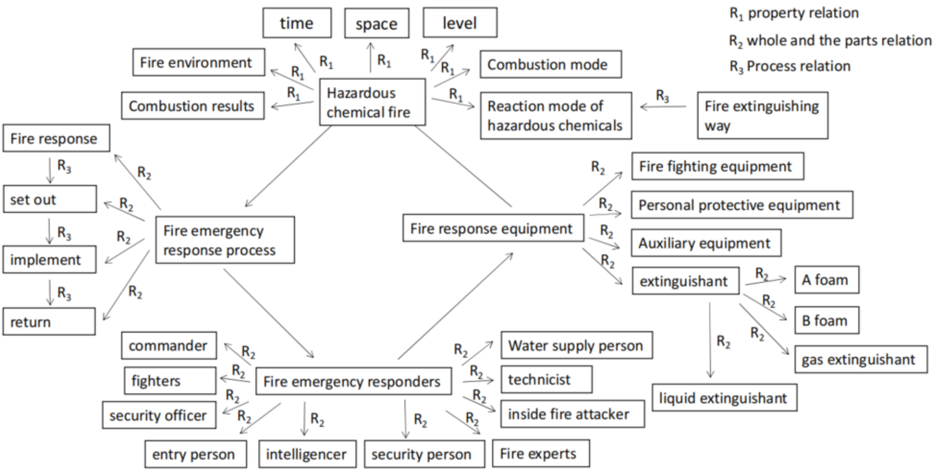

Figure 2. Relational graph of HC-FERO

Generally speaking, the main method used to calculate the similarity between two entities is the Jacquard formula, and some scholars choose cosine similarity. Let N(u) be the set of epistatic words owned by entity u, and N(v) be the set of epistatic words owned by entity v, then the similarity between u and v is:

Jaccard formula:
$$W_{uv} = \frac{|N(u) \cap N(v)|}{|N(u) \cup N(v)|}$$

Cosine similarity formula:
$$W_{uv} = \frac{|N(u) \cap N(v)|}{\sqrt{|N(u)| * |N(v)|}}$$

The set S(u,K) shows the correlation matrix from which we can find the K entities that are most similar to the target entity u. All supernumerary words owned by entities in S are extracted, while the supernumerary words already owned by u are removed. If each candidate epistatic i is taken into account, then the formula for calculating the degree of interest of entity u is defined as follows:

$$p(u,i) = \sum_{v \in S(u,K) \cap N(i)} w_{uv} * r_{vi}$$

In the given formula, r_{vi} refers to the degree of possession of entity v by i.

4. Hazardous Chemical Fire Emergency Ontology Evaluation

"11 • 15" bottled liquefied petroleum gas leakage and deflagration accident in Bengbu(Anhui province) is a large production safety liability accident. At about 6:17 on November 15, 2019, a fire accident occurred in Building 853, Station New Village, Huaihe Road, Longzihu District, Bengbu city, resulting in 5 deaths, 3 injuries and direct economic loss of 4.522 million YUAN [14]. Considering that this accident presents typical type characteristics, it is very suitable to be used as a case of ontology evaluation. Based on the knowledge model expressed by HC-FERO, the knowledge fragments in "11 • 15" bottled liquefied petroleum gas leakage and deflagration accident are described,Based on Figure 3, HC-FERO has achieved an accurate description of the fire accident.

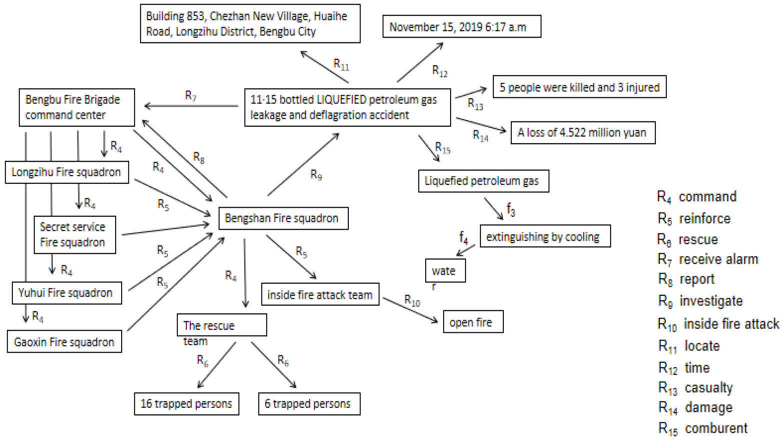

Figure 3. Relational graph of "11 • 15" accident

5. Peroration

The establishment of HC-FERO implements for hazardous chemical fire emergency response domain knowledge integration and help get the precise knowledge of emergency decision-making, so as to speed up for hazardous chemical fire emergency response speed, promote hazardous chemical fire emergency response ability, build hazardous chemical fire rescue emergency response knowledge map. In this way, the sharing and utilization efficiency of professional knowledge in emergency response can be improved, and professional rescue team can adapt to the task requirements of "all-disaster and large-scale emergency response" preferably.

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