Ontology Design of Meteorological Disasters

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With the development of science and technology, the demand of knowledge sharing and reuse forces people to reconstruct the ontology of the existing knowledge. In philosophy, ontology is defined as the nature of being, existence or reality. Computer science borrows this theory, constructing the ontology of a certain field [1] of the real world by abstracting and summarizing this field into a set of concepts and relations between them. Meteorological disasters mainly refer to the disasters caused by the natural phenomena in fields as meteorology, agriculture, geology and marine. The management of meteorological disasters based on ontology not only concerns the disasters' classification, naming and relationship between each other, but also concerns the grading and quantitative definitions. Emergency Response Law of the People's Republic of China classify the meteorological disaster's urgency, development momentum and potential risks into four grade, marked with red, orange, yellow and blue. Under the guidance of the Emergency Response Law, relevant departments promulgate the definition and identification of warning of meteorological disasters. The country formulates a series of standards on the classification of the meteorological disasters in agriculture, meteorology, ocean, land, grasslands, forests and geology. From the perspective of Internet, the meteorological disaster related law, standards, scientific data and knowledge are still lack of ontology based integrated expression. It causes the difficulty of converting terms of meteorological disasters to a common understanding of all trades and the difficulty to ensure accuracy and real-time of the warning of meteorological disasters.

In 2004 the W3C released the Web Ontology Language OWL (Ontology Web Language), which made knowledge description, network sharing and reuse a reality. In OWL, ontology is the formal representation of a set of concepts and their relationship in a certain field. OWL's basic description logic [2] is the structured logic which is a collection of knowledge representation language that develops on the basis of propositional logic and first order logic. Internet knowledge sharing as its starting point, it has no barriers of technology application promoting such as language, operating system, development environment and region in terms of expression of concept and knowledge. Using OWL to transform data/facts to knowledge and provide services in the field of artificial intelligence has been developed for decades [3]. Domestic and international researchers have carried out many studies on the application of OWL to the emergency response and disaster preparedness. GuiYuan Miao et al. proposed meteorological disaster's ontology

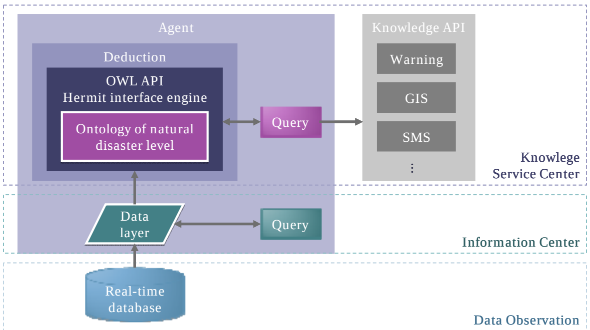

Fig. 1. Information service system based on ontology.

knowledge representation in the guidance of frame theory [4]. Chen-Huei Chou et al. put forward the method of tracking meteorological disaster via the Internet ontology [5]. However, these studies have yet to discuss in detail the classification and identification of the disaster level. This paper mainly discusses how to design the ontology knowledge base on the meteorological disaster levels right before and after the disaster happens under the guidance of Emergency Response Law, the definition of meteorological disaster's warning and meteorological disasters standards. By using Web ontology language to abstractly express the national regulations and standards, the transformation of real-time weather data to knowledge of meteorological disasters can be accomplished. The Web ontology language OWL's Internet-based design can meet web sites' design standard seamlessly, and provides the real-time dynamic web publishing services to serve the public. As the class in OWL can not be directly used as attribute, the building and operation of relationship between concepts in OWL is usually completed through object attribute or N-ary relation model. N-ary relational operation obtains the logical result through indirect reasoning. However, the indirect feature of N-ary relation model causes many additional definitions, which makes the structure of knowledge base more complex. This paper describes compound proposition logic hierarchically in the equivalent axioms [6], avoiding to use object properties in the equivalent axioms, thus avoiding the use of object property or N-ary relational model and simplifying the structure of the ontology knowledge.

Fig. 1 is the software architecture of our ontology-based service system, which can be divided into three levels. Data observation is the bottom level, and Information Center in the middle, refers to the conventional information acquisition method. The acquired information is raw data like temperature, rainfall, humidity and so on, which have to be processed afterwards in order to be used in service. The upper level, named as Knowledge Service Center is our main contribution. After the ontology of natural disaster

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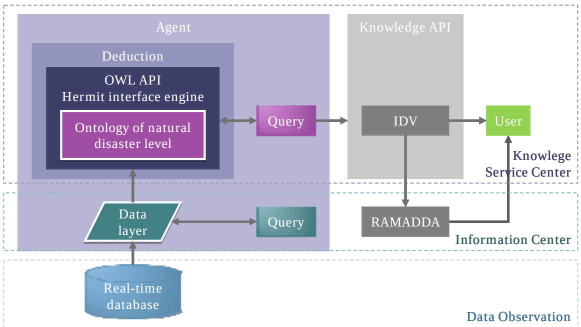


Fig. 2. Structure of ontology-based meteorological disaster alert system

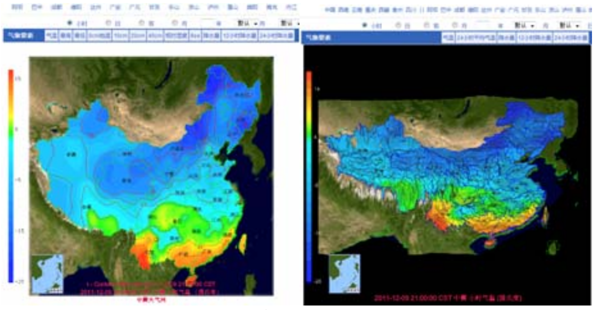
level is built up, the raw data can be transformed into knowledge data through the OWL API and Hermit inference engine. The knowledge data is then sent by the agent to the Knowledge API to be used by different services like early warning, GIS and SMS. From this chart, we can see that, the high-lighted block in purple "ontology of natural disaster level" is the core of the system, which can also be understood as the Knowledge Base of the system.

Transforming real-time data to analysis diagrams of ontology of meteorological disaster level is one of the specific applications of the ontology. Fig. 2 shows the process and the relationship between the ontology and OWL API, HemitT reasoning components, integrated earth science data visualization tools IDV, earth science content management system RAMADDA. The process can be described as: Original surface live data and the ontology of disaster level transform to disaster level data under the intelligent agent which is characterized by the inference engine, after the objective analysis and grid processing [7] of geographical areas, data is submit to the IDV to generate analysis diagrams for web publishing. Desktop or browser client can not only get the latest disaster analysis diagrams, but also query and review historical diagrams through the Earth Science content management system.

According to requirements of public weather services, we operated the column of ontology analysis diagram of meteorological disaster level. The first row of fig. 3 shows the general temperature data maps in 2D and 3D. These temperature data maps are generated using weight matrix pre-cutting of geographical boundaries with Barnes interpolation as [7]. The color in the diagram consistent with the disaster level colors (colorless, blue, yellow, orange, red), which interpret increasingly serious scales of disasters.

The real-time analysis diagram of meteorological disasters is the objective realization of disaster analysis. Firstly, it shows the four levels (blue, yellow, orange and red) of warning indicators through the visual analysis graphs. Secondly, it shows the observational data on which the disaster indicator relies. At last, it realizes the automatic analysis of disasters through the intelligence agent.

The ontology of meteorological disaster level is the bridge which connects the emergency response law, meteorological disaster standard, live monitoring data and the data model output. The network sharing feature of the ontology is helpful for the promotion of national / industry standards, as well as the objective and automated implementation of meteorological disaster warning, service and forecast under


(a) processed temperature data for China in 2D and 3D

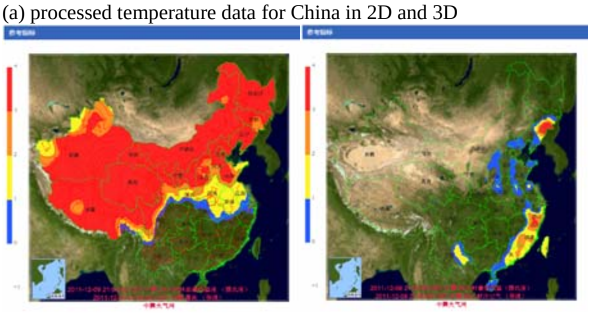

(b) left: frost alert map, right: cold wave alert map, after ontology reasoning and analysis

Fig. 3. General temperature data maps, which we cannot see the disaster information directly, are demonstrated in the first row. The second row shows the ontology-based disaster alert maps (frost and cold wave).

the same standard. The level classification is the soul of the ontology knowledge base.

With ontology design, we can process and manage the meteorological information in an efficient way to get products for different services. We apply the idea of ontology in meteorology disaster analysis. Combined with the IDV system, we can get the alert maps automatically. This approach is more efficient than conventional disaster analysis based on manual reports, in which the disaster centers are unclear. We believe, many other meteorological services can also benefit from the ontology design.

Improving and expanding the ontology knowledge base and developing more efficient reasoning algorithms are directions of our future work.

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