Building an Earthquake Evacuation Ontology from Twitter

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***Abstract*—During the massive Tohoku earthquake, while landlines and mobile phone lines got stuck, Twitter were used to exchange information about evacuation. On 11 March, the number of tweets from Japan dramatically increased to about 33 million, 1.8 times higher than the average figure. However, since texts on Twitter are unstructured data, are more complex than other text media, it is difficult to find a suitable evacuation center. Not only information in Twitter, people but also need to combine other information such as map information, shop information to find the suitable evacuation center. Since it takes much time to do these tasks, these manual processing are not suitable in the emergency status. Therefore, we need an approach to help computers to understand the meaning of evacuation, and to provide the most suitable evacuation center based on earthquake victims' behaviors in real-time. In this paper, we firstly design an earthquake evacuation ontology. Secondly, we indicate that by using this ontology, computers can provide the most suitable evacuation center based on earthquake victims' behaviors in real-time.**

***Keywords*-Earthquake; Twitter; Ontology; Social Web**

I. Introduction

On March 11, when the massive Tohoku Earthquake occurred in Japan, it was estimated that around 10 million people were away from their homes and 3 million of them found it difficult to return in Tokyo area [10]. Many reports said that a lot of people, who needed to evacuate, had problems finding the nearest evacuation center which the government and companies set up for them, since they were not able to figure out where they were [11]. Also, it is said that within the next 30 years, there is an 87% of possibility that an 8.0 magnitude earthquake occurs, with an epicenter in the northern Tokyo Bay. At that time, the number of people who will have difficulties returning home is expected to reach an amount of 6.5 million [4]. Therefore, the way of providing information about evacuation centers for those people is an important issue in the future.

Moreover, when earthquakes occur, people are in a state of confusion thus it is also important to provide real-time and appropriate information. On the day the Tohoku earthquake hit, while landlines and cell phone lines were blocked, social media networks like Twitter [18] were used to obtain information of toilets, evacuation centers, etc, provided by Tokyo municipalities and companies. Therefore, since Twitter provides real-time information, many people, not only individuals but also the Ministry of Education, University and the local governments used Twitter to disseminate valuable information that day. As a result, the number of tweets dramatically increased to about 33 million tweets on March 11. That was 1.8 times the average daily number of total tweets, which is about 18 million tweets [12]. Thus, it is possible to get information of evacuation centers from Twitter in disaster time.

Tweets are information represented by textual data. And therefore the search of these can be done by a word or a string. However, there is a problem that if the word is not written explicitly in tweets, users will not be able to find the information. For example, if a user wants to find an evacuation center near Jimbo town and search it using the keyword "Jimbo town", information such as: "Today, Gakushikaikan is open. Please feel free to use it. In here, two phones public are available, so people who have difficulty with the connection of mobile phone, do not hesitate to come here." may not be found because it does not have the keyword in the tweets. Thus, even when Gakushikaikan is approximately 1 minute from Jimbo town station, that information will not reach to the user and therefore, people who do not know that Gakushikaikan is in Jimbo town will not obtain any information.

Also, if trains stop on an unknown place for users, it would be more complicated in finding a suitable evacuation center by Twitter. For example, if you want to find an evacuation center near Yokohama, using the keyword "Yokohama", tweets as follows can be found: "Yokohama Arena is open to people with difficulty returning to their homes" or " For people with difficulty returning to their houses, Pacifico Yokohama will be opened to stay. " However, for people who have no knowledge about the place where they are, it is difficult to decide which one is the best place for them.

Therefore, in order to obtain the necessary information, people need to understand the situation, then enter or combine the keywords and finally process them by using other services such as Google maps [19]. Nevertheless, it is difficult to do all these process in a state of emergency. Hence, providing appropriate information automatically by using computers is required. And the most important issue

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is to describe the real-world information in a form that computers can understand it. By describing the information in a comprehensible form to computers, we will be able to provide users with the appropriate information. Thus, in order to achieve this, we designed an evacuation ontology that defines explicitly the attributes and relationships between concepts

The main contributions of our proposed evacuation ontology are summarized as follows:

1) Computers can provide appropriate information about evacuation centers in response to the users' situation.
2) It excels in scalability and connects with external ontology (such as radiation ontology) flexibly.

The remainder of this paper is organized as follows. Section 2 provides the definitions of the evacuation ontology and the explanation of how to build it. In Section 3, we will carry out and explain the results of an evaluation experiment to demonstrate the effectiveness of our method proposed. In Section 4, we will discuss about related work. Finally, conclusion and future work will be described in Section 5.

II. BUILDING EVACUATION ONTOLOGY

A. Components of evacuation ontology

To provide adequate information of evacuation centers according to the users situation, It is needed the evacuation centers information, relationships between information and information, and also a vocabulary to describe these.

Evacuation centers of the real world are modularized as shown in Figure 1. Evacuation centers have information of location. Location has name, latitude, longitude and address as an attribute of evacuation. Direction is divided into prefectures, ward and street. In evacuation centers are distributed products, and also evacuation centers have a starting time and an ending time. Evacuation after the ending time is not possible. In addition, the capacity of evacuation centers for lodge people is limited and an overload in capacity is not possible.

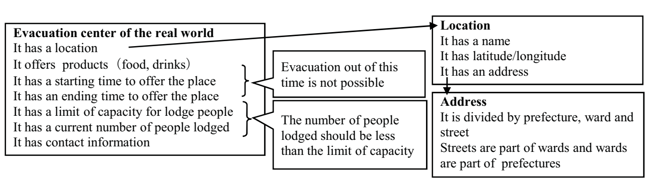

Figure 1. Concept of an evacuation center in the real world

Based on the evacuation center model, the class of the evacuation ontology is defined as shown in Table I.

In this evacuation ontology, external ontology was used as a reference to describe attributes that defines evacuation centers information (opening time, closing time, address, latitude and longitude). Table II shows the external ontology that was referred.

Table I
THE MAIN CLASSES OF AN EVACUATION ONTOLOGIES

Class Name	Brief explanation
EvacuationClass	Information of evacuation center
WhereClass	Location of evacuation center

Table II
EXTERNAL REFERENCE ONTOLOGY

Namespace prefix	Namespace URI	Content
tl:	http://purl.org/NET/c4dm/timeline.owl	Time Line Ontology
vcard:	http://www.w3.org/2006/vcard/ns	vcard Ontology
geo:	http://www.w3.org/2003/01/geo/wgs84_pos	Geo Ontology

The table III shows each attribute of the evacuation ontology.

Table III
THE ATTRIBUTE OF THE EVACUATION ONTOLOGY.

Class Name	Attribute Name	Brief explanation
EvacuationClass	label	User-readable label
	where	Location of Evacuation Center
	provider	Products distributed in evacuation centers
	tl:start	Evacuation center's starting time
	tl:end	Evacuation center's ending time
	vcard:email	Contact information（e-mail)
	vcard:tel	Contact information (telephone number）
	status	Availability of the evacuation center
	reliability	Reliability of information
WhereClass	label	User-readable label
	vcard:region	Address information (prefectures level)
	vcard:locality	Address information (ward level)
	vcard:street-adress	Address information (street level)
	geo:lat	Latitude
	geo:long	Longitude
	radioactivity_node	Reference node for external ontology

B. The criteria to build our evacuation ontology

The criteria to build our evacuation ontology are as follows.

1) Vocabulary provision
   We provisioned a basic vocabulary in order to describe the evacuation centers information and relationships between them.
2) Cooperation with existent ontology.
   Since, several ontology of diverse purposes exists already, we designed the evacuation ontology considering the simplicity of combination between existent ontology and the evacuation ontology.
3) Japanese-English Conversion
   During the earthquake in Tohoku, a lot of foreigners were unable to obtain information of evacuation centers [20], due to the language problem. Therefore, when building this ontology we made it able to provide information in English.

C. Description method

We described the ontology making use of RDF (Resource Description Framework)[21], RDF schema and OWL (Standardized in W3C). In this research, we described the ontology by using N3 [13] due to: it describes the RDF Model is a easy way, it is a useful notation to represent ontology terms (OWL and so on) and RDF schema (used to vocabulary definition). Based on the criteria of section 2.1, a part of the N3-written evacuation ontology class and attribute is as the following Figure 2 and Figure 3 shows.

```
### Definition of Class
:EvacuationClass    a                  owl:Class ;
                    rdfs:subClassOf    owl:Thing .
:WhereClass         a                  owl:Class ;
                    rdfs:subClassOf    owl:Thing .
```

Figure 2. Class of the evacuation ontology

```
### Definition of properties
:where     a                 owl:ObjectProperty ;
           rdfs:label        "where" ;
           rdfs:domain       :EvacuationClass ;
           rdfs:range :      WhereClass .
:provider  a                 owl:ObjectProperty ;
           rdfs:label        "provider" ;
           rdfs:domain       :EvacuationClass ;
           rdfs:range :      EvacuationClass .
```

Figure 3. Attributes of the evacuation ontology

According to these classes and attributes,the evacuation center information is described as the Figure 4 below.

```
:shinjuku_high_school_evacuation  a   :EvacuationClass ;
                :where                :shinjuku_high_school ;
                :provider             [rdfs:label "飲み物"@jn, "drinks"@en] ,
                                      [rdfs:label"暖房"@jn, "heated"@en] ;
                tl:start              "2011-03-11T21:00:00"^^xsd:dateTime ;
                tl:end                "2011-03-13T15:00:00"^^xsd:dateTime ;
                :people_max           "100"^^xsd:nonNegativeInteger ;
                :people_current       "89"^^xsd:nonNegativeInteger ;
                vcard:email           <S1000025@section.metro.tokyo.jp> ;
                vcard:tel             [ a vcard:Work ; rdf:value "03-3354-7411"] ;
                :status               "1"^^xsd:boolean ;
                :reliability          "1.0"^^xsd:double .
```

Figure 4. An example of the evacuation ontology

D. Method of extracting instance for evacuation ontology

The flow when extracting the evacuation ontology's instance are summarized as follows:. Firstly, it obtains information of the available evacuation centers by using the hash tag “evacuation center” in twitter. For example, when appears an expression such as: “School rooms and gymnasiums in Shinjuku Metropolitan High School have been opened. These have heating system, there are drinks and also TV information is provided.” the evacuation center's name (Metropolitan Shinjuku High School), the products offered (heating, drinks) and time (2011/3/11 20:10:35) are extracted from this tweet(1).

Secondly, based on the information acquired in (1), it obtains additional information through the web by using Google map [19] (to obtain the evacuation center address), Geocoding [24] (to obtain the latitude and longitude of the evacuation center), Google Translation (to translate Japanese information into English) [23] (2). In other words, it obtains information in real time even though these kind of information are not written in twitter. Finally it complements the information(3).

III. Evaluation

In this section, to demostrate the flexibility and effectiveness of our proposed evacuation ontology, we carried out the following two evaluations:

1) If the machine can provide appropriate information according to the situation (actual position and time) of users, using the evacuation ontology.
2) If the evacuation ontology is flexible and scalable.

A. Providing appropriated information of evacuation center

By using SPARQL (Simple Protocol And RDF Query Language)[26], we evaluated if it is possible to offer users adequate information of evacuation centers according to the localization and time of users (the Figure 5 shows an example of the SPARQL Query.) This query obtains information of evacuation centers and the products offered in it according to the localization (Shinjuku) and time (18:00-09:00 March 12th, March 11th) of users.

```
SELECT DISTINCT ?location_name ?product
                ?start_time ?end_time
WHERE{          ?evacuation tl:start ?start_time .
                ?evacuation tl:end ?end_time .
                ?evacuation :where ?location .
                ?location rdfs:label ?location_name .
                ?evacuation :provider [rdfs:label ?product] .
                ?evacuation :where ?where .
                ?where vcard:locality ?locality .
FILTER(         ?locality ="Shinjuku"@en &&
                ?start_time <= "2011-03-11T18:00:00"^^xsd:dateTime &&
                ?end_time >= "2011-03-12T06:00:00"^^xsd:dateTime &&
                lang(?location_name) = "en" && lang(?product) = "en" )}
```

Figure 5. Using this query , It can get information of evacuation center according to localization and time.

The results obtained from the query of Figure 5 are shown in table IV.

Table IV
The results from the query Figure 5

Location_name	“Shinjuku high school”@en	“Shinjuku high school”@en
Product	“hotdrink”@en	“Heating”@en
Start_time	2011-03-11T17:00:00	2011-03-11T17:00:00
End_time	2011-03-12T09:00:00	2011-03-12T09:00:00

Figure 6 shows the structure of the system. And by inputting the SPARQL query of Figure 5 to the repository endpoint, information updated in real-time can be obtained. Therefore, we can say that using this ontology, it is possible to obtain information of evacuation centers according to the place and time users are (Table IV).

Next, to demonstrate the efficiency of this ontology, we made comparisons between this and the conventional

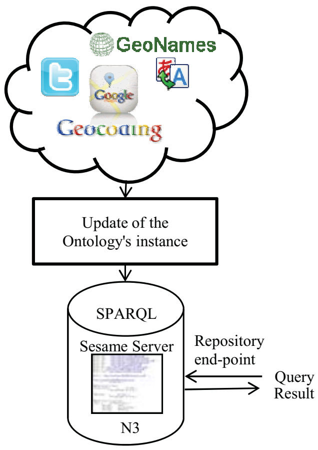

Figure 6. The structure of the system

approaches (such as Google [22] or Twitter), based on the next scenarios:

1) Getting information of all the evacuation centers within the designated parameter.
2) Getting information of all the evacuation centers that are open according to the designated address.
3) Getting information of all the evacuation centers in Minato-ward, Tokyo.
4) Getting information of the evacuation centers that are open according to the time predetermined.
5) Getting information of the evacuation centers that are open within the time designated.
6) Obtaining information of the evacuation centers opened right now and also were opened 15 minutes ago.
7) Getting information of all the evacuation centers opened within the designated parameter.
8) Getting information of all the evacuation centers able to be used in cooperation with outside radiation ontology.
9) Getting information of the products offered by the nearest evacuation center open.

Table V
RESULTS OF THE COMPARISON

	Num of Query	Num of times	Times (s)	Services
Scenario #1	5〜	4	1800	2
Scenario #2	2	2	420	1
Scenario #3	2	5	1800	2
Scenario #4	2	4	300	1
Scenario #5	3	5	1800	1
Scenario #6	2	5	1800	1
Scenario #7	6〜	5	24000	2
Scenario #8	3	5	420	1
Scenario #9	6	5	2400	1

The table V shows the results of each scenario. The numbers inside the Figure V means as follows (from left to right): Number of needed query for the search, Number of times for process, needed time for the search, Number of services used when searching. In the scenario #1 we made a search for all the evacuation centers that are open within the set up parameter (50 km; maximum distance a human can walk in one time). For example, if we use the conventional services, the search flow would be as below:

Step1: Get information of all the names of the places that appear inside the map according to the determined parameter.
Step2: After setting as a query one of the names of the places that appeared, use the hushtag “#hinan” or the query “evacuation center” and make a new search by combining these two.
Step3: The user looks at the results and obtains information of the available evacuation centers.

These are the steps in order to find an available evacuation center that is within the parameter of 50 km. It took about 30 minutes to get results. And also users must decide by themselves which one is the most appropriate place from these searching results.

On the other hand, since the evacuation ontology proposed describes the concept of distance as an attribute of evacuation, it can get all the information of the evacuation center within the predetermined parameter (50km.) and also based on the concept of distance it can obtain information of the nearest evacuation center for users.

Also, using the traditional search for getting information of evacuation centers located in Minato ward (scenario #3) occurred problems such as; Even when “Keio University, Mita Campus” is in Minato ward, it do not appeared since tweets did not have the keyword “Minato Ward.”

Table VI shows the search results obtained using the keyword “Minato Ward” and “#Hinan.”

Table VI
RESULTS OF SCENARIO #3, KEYWORD “MINATO WARD”, “#HINAN”

No.	Tweets obtained after executing scenario #3
1	Minato Ward Learning Center accepts people with difficulty returning to their homes #jishina #earthquake #tokyo #hinan, 2011-03-11 21:49:00
2	【Minato ward】Tokyo University of Marine Science and Technology, Shinagawa Campus（MinatoMinami）▼【Shinjuku ward】Shinjuku Local Joint Government Bldg（Hyakunincho）,JICA Research Institute（Ichigayahomura-cho）,Waseda University Auditorium Okuma（Nishiwaseda）▼【Bunkyo ward】University of Tsukuba, Otsuka Campus（Otsuka）,Ochanomizu University Myogadani Campus #jishin #hinan, 2011-03-11 23:57:00
3	Minato ward. We accept people in La Pista Shimbashi. Minato ward Learning Center. #jishin #earthquak #tokyo #hinan #shinbashi, 2011-03-12 00:08:00
4	【Facilities for people with difficulty returning to the house】Minato ward Shiba park 4-7-35 The chief temple of the Jodo Buddist sect has established a place of rest. We are accepting people. The monk is waiting at the gate of the temple for guide. #hinan, 2011-03-12 01:07:00

The table VI shows the information found using traditional searches. Using traditional searches you cannot obtain information such as “Keio University Mita Campus”, “Seishin Joshi University”, “Shinagawa Prince Hotel” (Table VII), even when all the places mentioned above locates in Minato ward, due to it not contains the keyword “Minato ward”.

Table VII
AN EXAMPLE OF MISSING INFORMATION

No.	Tweets that not include the keyword Minato ward
1	**Keio University, Mita Campus**,Open. #jishin #earthquake #tokyo #hinan, 2011-03-11 23:37:00
2	Free Evacuation Places provided for people who have difficulties returning to their homes: Roppogui → ButagumiShabuan / Tokyo Bunka Kaikan, Ueno/ Ochanomizu → Liberty Tower Meiji/ Shinjuku → Times Square Takashimaya/ Ikebukuro → Rikkyo University 11, 14 building/ Hamamatsu Station → Mannen bridge Park building 7F/ **Shinagawa → Shinagawa Prince Hotel** #jishin #hinan, 2011/3/11 19:04:07
3	Schools Open for people who have difficulties returning to their homes: Rikkyo University/ Aoyama Gakuin University Aoyama Campus/ Sophia University/ Meiji University Surugadani Campus/ Tokyo University Komaba Campus/ Kogakuin University Shinjuku Campus/ Tokyo University of Scinece/ Seikei Univeristy/ **Seishin University**/ Tokyo institute of Technology Ookayama Campus/ Metropolitan Shinjuku high school / Tokyo University of the art, Ueno #hinan , 2011-03-11 22:45:00

On the other hand, by using our evacuation ontology, in which hierarchical relations and location concepts are described, the machine was able to understand that ”Keio University, Mita Campus” is located in Minato ward and therefore was able to obtain appropriated information. Thus we can say that; in emergency times, when the most important thing is to get information of high precision as soon as possible, using our ontology for search is highly effective.

B. Extensibility and flexibility

As mentioned in Section II.B, when building the evacuation ontology, in case that there is a vocabulary that has an equivalent concept already, there is no need to define a new vocabulary, but just to combine existing concepts. For example, in order to represent the information and attributes of evacuation centers, we utilized existent ontology; such as geo [14], time [15], Vcard [16], which have a concept of distance, time and address respectively. As this way, a great amount of ontology with various purposes exists. Therefore, there is no need to build a new ontology. That is why when expanding the ontology, if there is a vocabulary that shows an equivalent concept, it can be used in a flexible form.

In addition, as shown in Figure 10, each geo, Timeline and Vcard ontology, these are managed and operated individually. As a consequence, the ontology can be used without having to worry about managing and handling. Therefore, also comparing with the data base, which is of self-management, ontology could be considered to have the flexibility and it is easy to use.

Furthermore, when expanding the ontology, if there is a vocabulary that shows an equivalent concept, it can be used in a flexible way referencing from the existent ontology. For example, after the Tohoku earthquake occurred radiation was regarded as a problem. In this case, we expanded the evacuation ontology only referencing the existent radiation ontology, which Kanzaki [17] has designed and open to the public previously. For that reason, we can consider that the ontology is able to be connected flexibly and therefore, the evacuation ontology could be considered of great scalability.

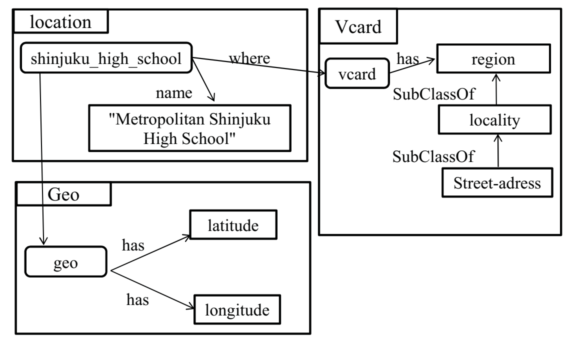

Figure 7. Method of building evacuation ontology

IV. RELATED WORK

As researches that recommend Action-Patterns in moment of evacuate according to the situation of users, we can mention the investigation of Nakanishi et al [8] [5] [6]. These researches proposed to solve the existent problems by an system of simultaneous announcement. Since it is difficult to provide adequate information for each group of people evacuating, Nakanishi proposed a system that provides appropriate instructions to each group separately from remote. Concretely, this is a communication support system that, by mapping all real space information obtained from sensor as an object in the virtual space, and by making the administrator able to interact directly with this object, can provide instructions for the large crowd of people at the time of disaster, or also when a individual user requires. In this system the administrator provides instructions using the control interface of a touch panel in a cell phone. Moreover, this induction system needs sensors to detect the location of people who evacuated, and to detect the condition of evacuation places. Therefore, Nakanishi et al in order to determine the location of people who evacuated, and obtain the situations of the places around them, installed 12 cameras in the lobby and 16 cameras on the platform of Kyoto subway station and make an experiment. Through this experiment, they have shown that the induction system they proposed is effective [7]. However, it is important to point out that installing sensors everywhere in advance to identify locations and situations is almost impossible. And what is more, in this system an administrator is needed to provide induction.

Also, as a previous study we can mention the work of Sasaki et al [1], which obtains information about the earthquake using Twitter. This is a method that regards a Twitter user as a sensor (Social sensors) and acquires events, such as earthquake, from a users' tweet. Firstly, it extracts sentences that contain "Earthquake", "shakes" from users' posting. Secondly, using SVM (Support Vector Machine) [9] classifies whether the postings refers to earthquake. Finally, after deducing that these postings refer to earthquake, it guesses the place where the earthquake has occurred. Moreover, we can mention the previous study of Okazaki et al [2]. Through SVM this system obtains information of an earthquake has occurred. After that, it gives users previous notice of the earthquake by e-mail faster than the earthquake center. One of the objectives of Okazaki et al is to use the twitter data semantically. Nevertheless, since the information is not systemized the computer does not understand it semantically.

Finally, as previous studies using ontology, also it is mentioned an event ontology from Noh et al [3], [**?**]. Unfortunately, the only targeted domains are books, electronics, and touristic places, and the information acquired is from blogs.

V. Conclusion

In this paper, we proposed a structure in which a computer could retrieve the information from social media networks such as Twitter, through the evacuation center ontology. For people to retrieve accurate information, they must go through a lot of steps to process the information. On the contrary, a computer can retrieve the information needed, process it, and show the accurate information the user is looking for. Also, by the proposal of the ontology, it can be determined that the scalability became more flexible. Through this evaluation, we also proved that the computer was able to adapt to its changes, and provide the accurate information matching the current situation in real-time.

As future work we can mention the following: obtain the ontology data automatically, and also examine about the possibility of an interface that obtains data from the information that users input directly, even when it is not upon Twitter or in the Web.

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