A Communication and Tracking Ontology for Mobile Systems in the Event of a Large Scale Disaster

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Abstract. Communication and tracking capabilities during and immediately after a large-scale natural disaster are one of the most important components of speedy response and recovery. In that, it discovers affected people and connects them with their families, friends, and communities with first responders and/or their support computational systems. Capabilities of current mobile technologies can be expanded to become effective large-scale disaster tool aid. To facilitate effective communication and coordination across different parties and domains, ontologies are becoming crucial in providing assistance during natural disasters, especially where affected locations are remote, affected population is large and centralized coordination is poor. Although there are several existing competing methodologies with regard to as how an ontology may be built, there is not a single right way to build an ontology. Furthermore, there is not a (de facto standard) Disaster Relief Ontology, although separated related ontologies may be combined to create an initial version. This article discusses our on-going development of an ontology for a Communication and Tracking System (CTS), based on existing related ontologies, that is aimed to be used by mobile applications to support disaster relief at the real-time. For future work, this ontology will be used to provide a multi-disciplinary knowledge foundation in a distributed multi-agent based environment, where mobile devices, rescue workers and their organizations are modelled and functioned as distributed and collaborative agents to support each other in the event of a large-scale natural disaster.

Keywords: Ontology, Mobile Application, Semantic Web, Linked Data, Communication, Natural Disaster, Earthquake, Disaster Relief, Intelligent Systems, Decision Support Systems.

1 Introduction

In recent years, earthquake disasters have caused terrible losses, fatalities and missing people. Sichuan, China earthquake in 2008 killed at least 69,000 people, injured more than 374,000 [1], and left about 4.8 million homeless [2]. While, Haiti earthquake in January 2010, causing over 200,000 fatalities, 300,000 injuries and leaving over 1 million people homeless [3]. Another big impact earthquake is Pacific Ocean earthquake and subsequent tsunami in Japan in March 2011 that cost the Japanese economy more than $300 billion and caused unprecedented loss to the Japanese people, their environment, and the global economy [4].

A few of application system has been developed in a web and mobile application to fulfill tracking missing people, disaster management and emergency response. SEA-EAT blog, Nepal Earthquake Missing People on Facebook, Nepal Earthquake Missing People Website, PeopleFinder and others are amongst of well-known application developed for this purpose especially in very large-scale disaster. Some of the application are using a semantic web and linked data as a solution to integrate the information between multiple of agencies for top management to make a decision and also for reporting purposes but there are still gaps to be filled especially in a communication and tracking people during and after earthquake using an ontology in a mobile application.

Mobile phone nowadays is one of the top multi-functional devices which capable to be a broad range of application and able to serve people in communication. This is proved by the numbers growth from 4.3 billion users in 2015 and expected to become 5.07 billion users in 2019 [5]. We hope, with a linked data and ontology implemented in mobile application, smart device can assist agencies and community to track people who need a help or trapped in the prone area, rescuer can easily find victims nearby their current location and the important thing is survivors can easily find the nearest shelter or agencies who can help them.

This article will discuss on the ontology development in linked data and semantic web technologies [6] that can be used especially in mobile phone application to make people connecting with others during the large-scale disaster. We aimed to improve the existing current and stable ontologies to fulfill the communication and tracking people using a mobile phone as an instrument. Therefore, step by step on the development of Communication and Tracking Ontology (CTO) will be discussed and the remainder of this paper is structured as follows. In Section 2 will provide a few of related work and motivation in ontology development, Section 3 describes the process of how the CTO was developed. The merging and building CTO in Section 4, while section 5 gives an overall conclusion and future work.

2 Motivation and Related Work

The main motivation for developing a CTS is to provide effective communication and assist coordination among victims, communities, rescuers and organizations who are involved directly or indirectly during and just after a large-scale disaster, thereby providing speedier recovery and relief to the victims as possible. With a mobile phone supporting internet connection on hand, people/organization may use their smart devices to know about how to help people especially nearby their location without knowing where the exact location, address, who's their family to contact and also they don't know even victims background information such as their name or blood type. The stakeholders (government agencies) of this domain find it increasingly difficult to coordinate and respond to emergency situations. The result of this has increased the number of deaths, delay in access to basic needs and slower recovery time [7]. There are many types of the disasters exist in this world such as epidemic, eruption, fire, flood, forest fire, hailstorm, heat wave, hurricane, ice storm, lahars, landslides, limnic eruption, maelstrom, mudslide, sinkholes, storm, thunderstorm, tornado, tsunami, typhoon, volcano, wildfire and terrorist bombing [8][9][10][11][12][13]. Among them, an earthquake is one of the most poorly-understood disasters that may happen with no warning sign and nobody will know for sure, including geologist scientist concerning where and when it may happen [14]. The CTO is very important to enable the systems, find and collect the information from many resources on the net such as the name of victims, their places, their relative and their current coordinate. Therefore, the objectives to build up the CTO are:

1. To reduce fatalities and missing people in case of an earthquake.
2. To help personnel to monitor a real-time information about missing people during an earthquake.

From Table 1, the Earthquake Reports from United States Geological Survey (USGS) [15] show to the world that the big magnitude (magnitude > 6.0) impact earthquake happened yearly since 1990. The year 2010 history in Haiti indicated a large number of fatalities with 316,000 people and many of them might not be traced (missing) until today.

Table 1. No of Earthquakes and Fatalities from year 2000 – 2014 by US Geological Survey (USGS)

Largest Earthquakes					Deadliest Earthquakes			
Year	Date	Magnitude	Fatalities	Region	Date	Magnitude	Fatalities	Region
1990	16-Jul	7.7	1,621	Luzon, Philippine Islands	20-Jun	7.4	50,000	Iran
1991	22-Apr	7.6	75	Costa Rica	19-Oct	6.8	2,000	Northern India
1991	22-Dec	7.6	-	Kuril Islands				
1992	12-Dec	7.8	2,519	Flores Region, Indonesia	12-Dec	7.8	2,519	Flores Region, Indonesia
1993	08-Aug	7.8	-	South of Mariana Islands	29-Sep	6.2	9,748	India
1994	04-Oct	8.3	11	Kuril Islands	06-Jun	6.8	795	Colombia
1995	30-Jul	8	3	Near Coast of Northern Chile	16-Jan	6.9	5,530	Kobe, Japan
1995	09-Oct	8	49	Near Coast of Jalisco Mexico				
1996	17-Feb	8.2	166	Irian Jaya Region Indonesia	03-Feb	6.6	322	Yunnan, China
1997	14-Oct	7.8	-	South of Fiji Islands	10-May	7.3	1,572	Northern Iran

Largest Earthquakes					Deadliest Earthquakes			
Year	Date	Magnitude	Fatalities	Region	Date	Magnitude	Fatalities	Region
1997	05-Dec	7.8	-	Near East Coast of Kamchatka				
1998	25-Mar	8.1	-	Balleny Islands Region	30-May	6.6	4,000	Afghanistan-Tajikistan Border Region
1999	20-Sep	7.7	2,297	Taiwan	17-Aug	7.6	17,118	Turkey
2000	16-Nov	8	2	New Ireland Region, P.N.G.	04-Jun	7.9	103	Southern Sumatera, Indonesia
2001	23-Jun	8.4	138	Near Coast of Peru	26-Jan	7.7	20,023	India
2002	03-Nov	7.9	-	Central Alaska	25-Mar	6.1	1,000	Hindu Kush Region, Afghanistan
2003	25-Sep	8.3	-	Hokkaido, Japan Region	26-Dec	6.6	31,000	Southeastern Iran
2004	26-Dec	9.1	227,898	Off West Coast of Northern Sumatra	26-Dec	9.1	227,898	Off West Coast of Northern Sumatra
2005	28-Mar	8.6	1,313	Northern Sumatra, Indonesia	08-Oct	7.6	80,361	Pakistan
2006	15-Nov	8.3	-	Kuril Islands	26-May	6.3	5,749	Java, Indonesia
2007	12-Sep	8.5	25	Southern Sumatera, Indonesia	15-Aug	8	514	Near the Coast of Central Peru
2008	12-May	7.9	87,587	Eastern Sichuan, China	12-May	7.9	87,587	Eastern Sichuan, China
2009	29-Sep	8.1	192	Samoa Islands region	30-Sep	7.5	1,117	Southern Sumatra, Indonesia
2010	27-Feb	8.8	507	Offshore Maule, Chile	12-Jan	7	316,000	Haiti
2011	11-Mar	9	20,896	Near the East Coast of Honshu, Japan	11-Mar	9	20,896	Near the East Coast of Honshu, Japan
2012	11-Apr	8.6	-	off the west coast of northern	06-Feb	6.7	113	Negros-Cebu region,

Largest Earthquakes					Deadliest Earthquakes			
Year	Date	Magnitude	Fatalities	Region	Date	Magnitude	Fatalities	Region
				Sumatra				Philippines
2013	24-May	8.3	-	Sea of Okhotsk	24-Sep	7.7	825	61km NNE of Awaran, Pakistan
2014	01-Apr	8.2	6	NW of Iquique, Chile	03-Aug	6.2	729	near Wenping, China

Quite early on, a number of researches have shown that the emergency response domain can especially benefit from Semantic Web technology. Ontology has been used and some of the applications have been developed to find missing people and such as PeopleFinder that has been developed from the experience of Katrina hurricane [7]. Another research regarding the use of ontology of a web base application is a blog (SEA-EAT) that has been set up during the Asian tsunami in 2014. It was developed into an information exchange system for missing persons, requests for help and news updates [7]. For example, it had used an ontology as a knowledge base for sharing and extracting information. They have developed an ontology for situation awareness in crisis management to provide a contextual understanding of the post-disaster environment for different users.

Efforts to apply linked data and ontology in the field of emergency response are presented in recent researches on various facets. In the context of Weather Ontology, it was discussed in detail about AEMET, the Spanish Public Weather Service in [16] where they are using the ontology to make meteorological data publicly available via their website, as registered by its weather stations, radars, lightning detectors and ozone soundings. They also discussed the reusing of Time Ontology and Location Ontology to make it more suitable to cater for the Weather Ontology itself.

Many reports showed that a lot of people, who needed to be evacuated, had problems finding the nearest evacuation centers that the government and companies had set up for them, thereby receiving necessary assistant in a timely fashion [17]. Therefore, the way of providing information about evacuation centers for those people is an important issue in the future and research in [18]. In this article, they firstly design an Earthquake Evacuation Ontology and secondly, indicate that can computers provide the most suitable evacuation center, by using the ontology based on earthquake victims' behaviors in real-time.

3 Developing a Communication and Tracking Ontology to Assist Disaster Relief Efforts

Tom Gruber defined an ontology as the following "An ontology is an explicit specification of a conceptualization." [19]. It is important to understand what ontology is for. The ontology is to enable knowledge sharing and data consistency and as such an ontology is a specification for making ontological commitments.

There is no one "correct" way or methodology for developing ontologies and we have followed the seven top-level steps from [20] (see Figure 1) where the main component will be described from 3.1 to 3.7 below.

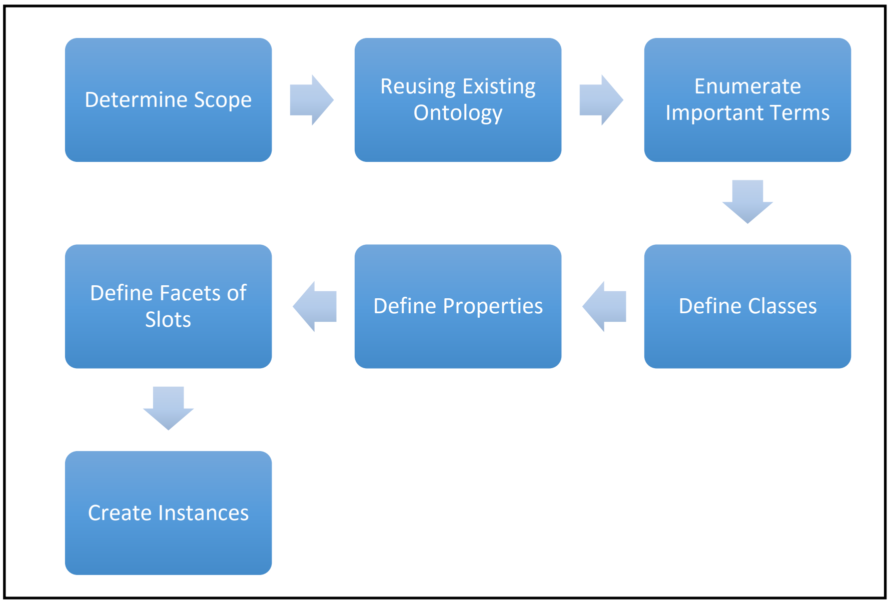

Figure 1. Seven Steps to Develop Ontology [20]

3.1. Determine Domain and Scope

Naturally, the concepts describing a communication and tracking during a large-scale disaster, type of disaster, weather, places, shelter, who to contact and etc. will figure into CTO. At the same time, it is unlikely that the ontology will include concepts for victims, rescuer, community and families to trace and connecting each other. The ontology will be designed focused to make people's traceable during the large-scale disaster, able to safe and secure after the disaster such as how community or agencies can help peoples in their surrounding (walking distance) and also victims can find the nearest shelter from their current location to get food, water or blanket supplied.

3.2. Reusing, Merging and Tailoring Existing Ontologies

Many ontologies are already available in electronic form and can be imported into an ontology development environment. This method called reuse process where this process is a cost effective way to build ontologies. The CTO was built by means of reuse, following an evolving prototyping life cycle. From 10 main ontologies component in CTO, several of them were reused from existing stable and maintained ontologies such as Friend of a Friend (FOAF) [21][22][23][24][25], weather [26][27][25], Disaster [28][25], Time [16][29], Places [23][16] and Location [16] ontology. Component from these ontologies has been selected and focused to the communication and tracking area.

3.3. Enumerate Important Terms

It is useful to write down a list of all terms that would like either to make statements about or to explain. The example of listed terms are in Table 2 below:

Table 2. List of Terms used in CTO

Terms		
Location	Mothers name	Latitude
Agent	Next of kin	Country/Region
Places	Nick name	Postal
Terrain	Cliff	State
Network Connectivity	Race	Network available
Time	Surname	Network down
Event	Fault	Accommodation
Weather	Disaster	Hostel
Support Group	Chemical emergency	Hotel
Help worker	Damn failure	Service apartment
Fire fighter	Earthquake	Agency building
Medical staffs	Explosion	Fire station
NGO	Fire	Hospital
Police	Flood	Police station
Red Cross	Flash flood	School
Person	Riverine flood	Commercial resources
Date of Birth	Landslide	Shopping mall
Blood type	Nuclear power	Shop
Contact Details	Radiation	Houses
Peninsula	Tsunami	Apartment
First name	Location	Flat
Gender	City	Landed house
Island	Coordinate	Other building
Religion Places	Longitude	Weather
Church	Shelter	Humidity
Mosque	Available capacity	Pressure
Temple	Total capacity	Temperature
Severity status	Support group	Wind
Red	Agencies	Hill
Green	Family	Mount
Yellow	Friends	Valley

Terms	
Time	Others
Date	Colleague
Duration	Neighbors
Start	Other individual
End	Military

Sources from [8], [9], [21], [23], [25], [26], [29], [30], [18], [31], [32], [33].

3.4. Define the Class Hierarchy

There are several possible approaches in developing a class hierarchy as mention in [34] but in this cases, a combination of the top-down and bottom-up approached in development process were used. Figure 2 below shows the classes and hierarchy for CTO.

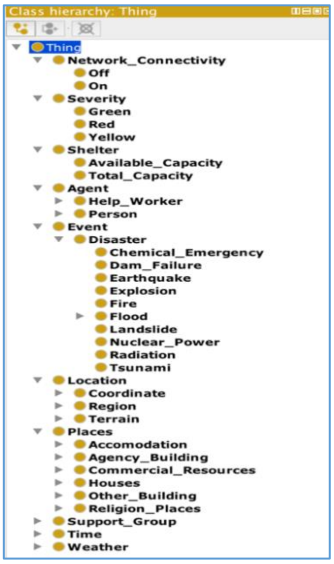

Figure 2. Classes and Hierarchy for CTO

3.5. Define Properties

For each property in the list, it will determine which classes will be described. The classes alone will not provide enough information to answer the competency questions. Once some of the classes defined, it must describe the internal structure of concepts. Figure 3 shows the list of property defined.

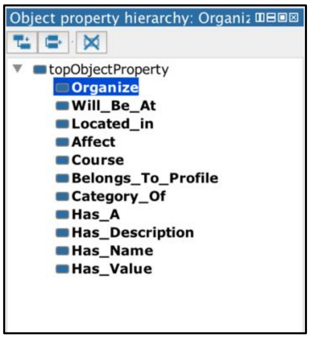

Figure 3. List of Property Defined in CTO

3.6. Define the Facets of the Slots

Slots can have different facets describing the value type, allowed values, the number of the cardinality values, and other features of the values. For example, the value of a name slot (as in "the name of shelter") is one string. That is, a name is a slot with value type String. A value-type facet describes what types of values can fill in the slot. Here is a list of the more common value types in this article:

- String : Is the simplest value type which is used for slots such as name: the value is a simple string
- Number : Value types of float and integer are used.
- Boolean : Yes–No flags.
- Enumerated : List of specific allowed values for the slot.
- Instance-type : Relationships between individuals.

3.7. Create Instances

The last step is creating individual instances of classes in the hierarchy for this CTO as below:

1. Defining an individual instance of a class required
2. Creating an individual instance of that class
3. Filling in the slot values.

The CTO example can create an individual instance Edinburgh-Mosque to represent a specific type of Places. The value of 1,000 is an instance of the class Total-Capacity representing Shelters. This instance has the following slot values defined.

- Total Capacity: 1,000
- Places: Edinburgh Mosque
- Location: City of Edinburgh
- Coordinate: Latitude : 55.9449995, Longitude : -3.1860282
- Event: Earthquake

4 Merging and Building the CTO

Ontologies have become core components of many large applications. Previous research shows a few ontologies for disaster management, emergency response and others have been done. For examples, AEMET Weather, Disaster Management, Management of a Crisis (MOAC), FOAF, etc. was developed and used in web application system for reporting purposes.

This article used the existing of ontologies mentioned above by other researches to addresses the issue on the CTS. To make this CTO suite with any application especially in a mobile application, a research to combine, reuse and create a new ontology must be carried out before testing can be done.

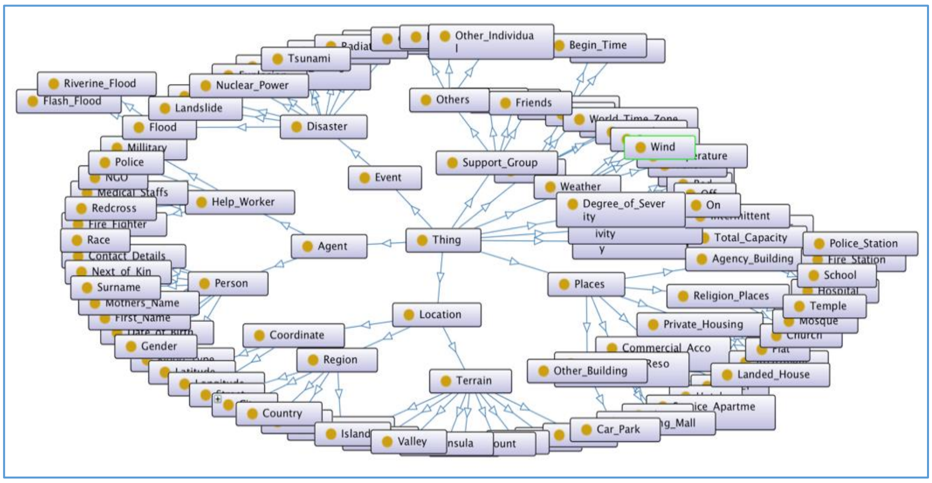

Figure 4. Details of Communication and Tracking Ontology

Figure 4 gives an overview of the CTO developed by using seven top-level steps as mention in section 3 above and it has been developed using Protégé v5.0.0. CTO posses 10 main classes in total to fulfill the communication and tracking issues during a large-scale disaster and emergency response. The main classes and their function are described below:

1. **Events**

   Event classes are one of the main classes in CTO. It is grouped all type of disaster which base from the research review in [7], [9], [11], [35] and etc. All type of disaster in this subclasses may occur during the earthquake event. From this classes, the information of the type of disaster can be traced from the system. The subclasses for the Disaster Event listed as Earthquake, Radiation, Fire, Tsunami, Chemical Emergency, Landslide, Nuclear power, Flood, Explosion and Damn Failure. Event class is shown in Figure 5 below.

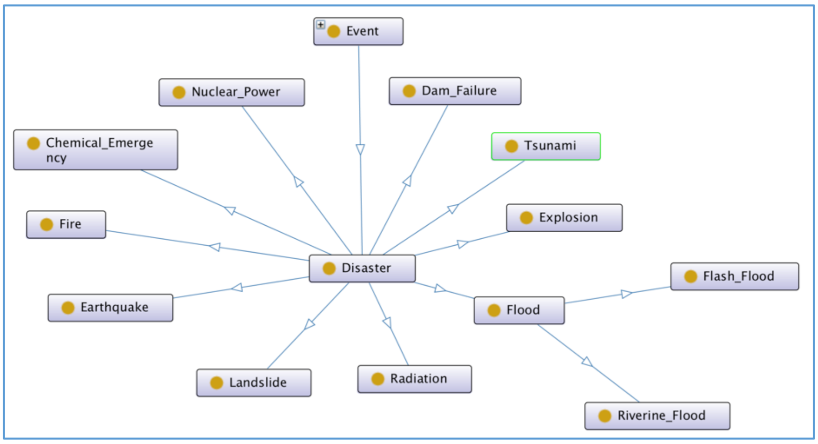

Figure 5. Event and the branch of Disaster in CTO (directional links indicate the sub-class relationships)

2. Agents

One of the important classes in CTO is Agent Classes which contain another 2 subclasses called Person and Help Worker. This classes are aims to spread the information about personal information and also the organization who can give a support for the community who maybe in a trap, injury and lost. The personal information can give a better idea to community or help worker to determine and get the background information during and before rescue process. The information about a Person is like Date of Birth, First Name, Surname, Mothers Name, Gender, Race, Contact Details, Blood Type and Next of Kin information. The other subclasses in Agent are Help Worker where the information supplied in this class are about the organization information for rescuers such as Police, Fire Fighter, Red Cross, NGO, Military and Medical Staffs. Refer to Agent Class in Figure 6 below.

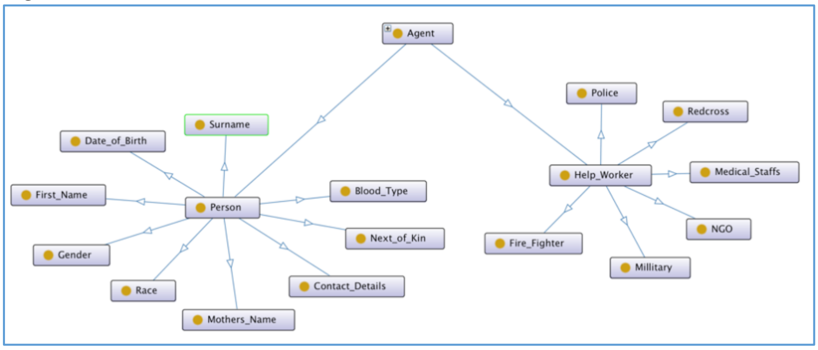

Figure 6. The Branch of Person and Help Worker in Agent Class (directional links indicate the sub-class relationships)

3. **Places**

Places are a group of locations that consist of formal building information which may help rescuer to know the last places of large-scale disaster victims and survivors. A part of this class will integrate with other classes in CTO such as Coordinate in Location Class and Shelter Class which will be described later in point no 5 and no 8 below. Places class contains 6 subclasses in layer 2 and 15 subclasses in layer 3. In layer 2 in Places class have subclasses such as Private Housing, Commercial Accommodation, Commercial Resources, Agency Building, Religion Places and Other Building. Other than that, layer 3 in this class contains a Temple, Church, Mosque, Police Station, Hospital, Fire Station, School, Shopping Mall, Shop building, Hostel, Service Apartment, Hotel, Flat, Landed House and Apartment. It grouped under the layer 2 classes as shown in Figure 7.

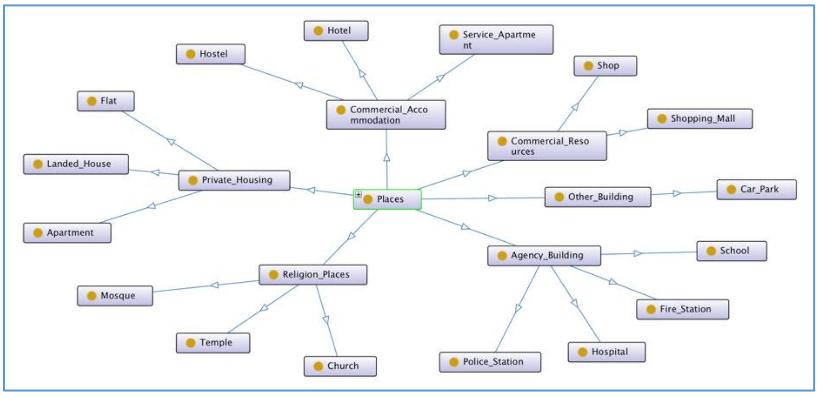

Figure 7. Branch of Places in CTO (arrowed links indicate the sub-category relationships)

4. **Weather**

Figure 8 shown the class of Weather where this class will group all the information about weather related to the large-scale disaster. This class will help people such as just after the large-scale disaster happen. It holds an information about humidity, temperature, wind, pressure and it is very important to the rescuer to know about their safety or the impact on them before they can help people in their area.

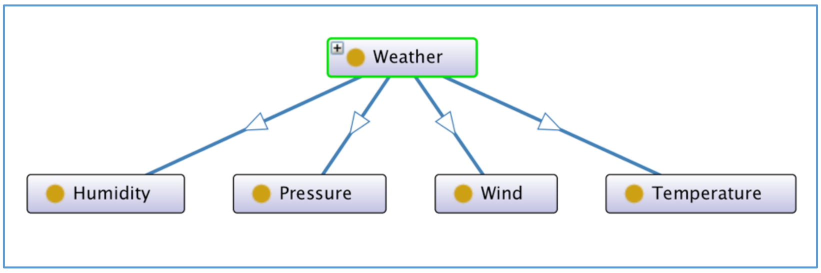

Figure 8. Branch of Weather in CTO (arrowed links indicate the sub-category relationships)

5. Location

Location is a simple class where it was assigned to grouped all the information about location such as Street, City, State, Country, Region, Postal Code, Terrain (Cliff, Island, Mount, Coast, Bench, Valley, Peninsula, Hill, Fault) [25], [36], [33] and Coordinate (Latitude and Longitude). As mention in Places Class, Coordinate Class will integrate with Places Class to provide more detail information. Figure 9 shown the Location Class in CTO.

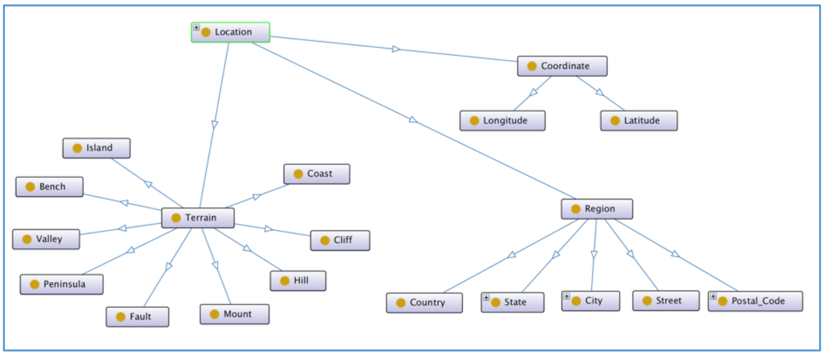

Figure 9. Branch of Location in CTO (arrowed links indicate the description relationships)

6. Time

Figure 10 show Time Class which contain the information about the Date, Duration, Time Point (Begin, End) and World Time Zone. Victims or rescuer during the disaster may know where are the places open as a temporary shelter.

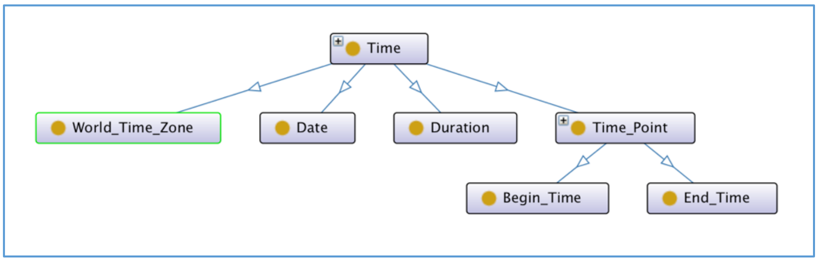

Figure 10. Branch of Time in CTO (arrowed links indicate the description relationships)

7. Support Group

The function of Support Group Class is to group user relative or next of kin information and agencies who can support or help victims during or after the large-scale disaster. This class contains information such as Friends, Agencies, Family or Others (Colleague, Neighbors, Other Individual). Figure 11 show the Support Group Class.

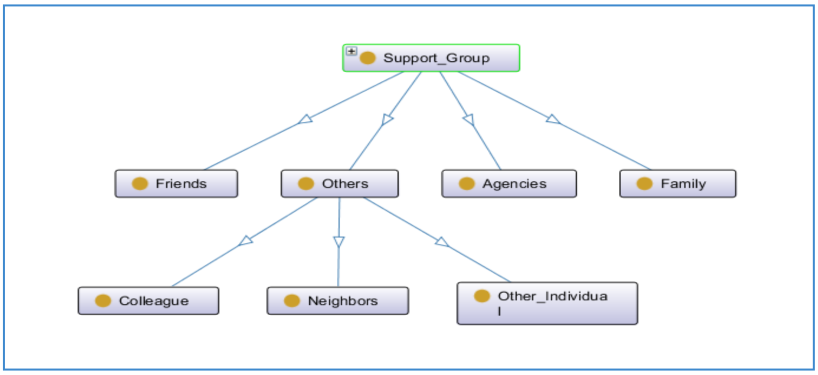

Figure 11. Branch of Support Group in CTO (arrowed links indicate the sub-category relationships)

8. Shelter Capacity

The Shelter Capacity class will hold the information about the total capacity and current availability shelter to make rescuer or victims will have a better choice to choose which shelter they want to take covered. Figure 12 shown the Class mentioned show the Shelter Class.

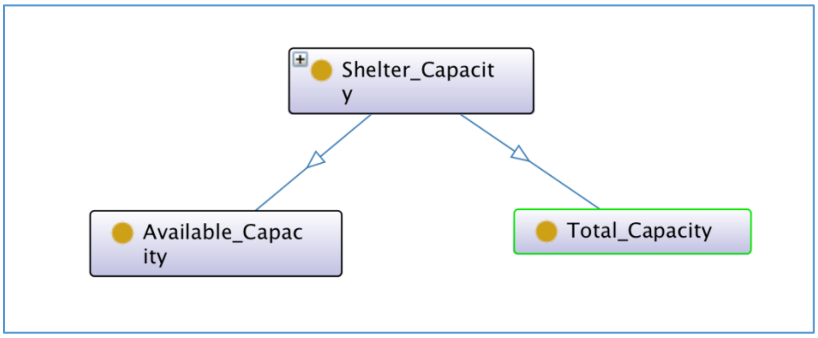

Figure 12. Branch of Shelter in CTO (arrowed links indicate description relationships)

9. Degree of Severity

Figure 13 shown the Degree of Severity Class where it will contain color code where it may green, yellow or red depend on the severity of the large-scale disaster. This is important to know what are the action should be taken to follow the International Disaster Relief Organization Standard of Procedure (SOP).

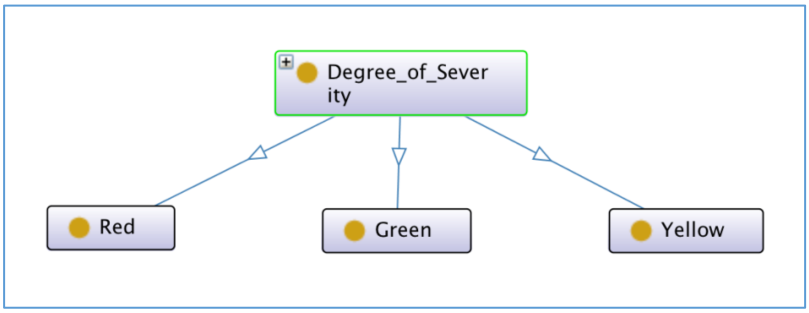

Figure 13. Branch of Severity in CTO (arrowed links indicate the description relationships)

10. Network Connectivity

Last class in this article to be discussed in CTO is Network Connectivity Class where the function of this class is to identify either the mobile phone network down, intermittent or shut off because of low battery. Figure 14 show the Network Connectivity Class.

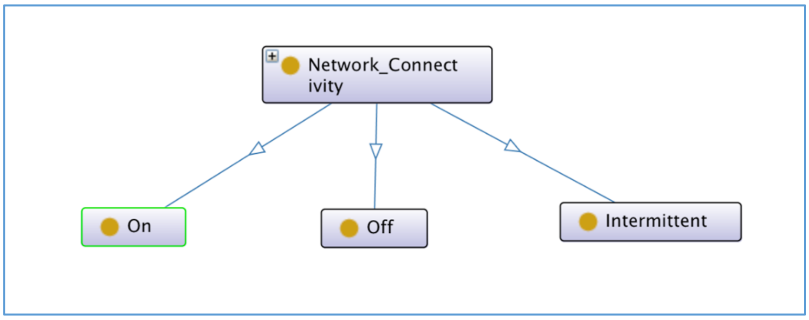

Figure 14. Branch of Network Connectivity in CTO (arrowed links indicate the description relationships)

5 Conclusion and Future Work

In a large-scale disaster, it is inevitable that many different types of stakeholders (victims, friends and families, disaster relief workers, other support workers and their organisations) are involved. It is common that different types of tasks will need to be carried out between the different types of personnel. It is paramount that all tasks must be well-coordinated and carried out in a timely fashion in order to save lives.

In order to support more effective and timely communication in the event of a large-scale disaster, we have therefore proposed to use ontology as a fundamental technology to pull the information from different relevant domains and store them consistently in one place, thereby promoting information sharing between personnel and interoperability between systems involved. The aim is to facilitate the right types of information to be shared at the right time and in the right format. When successful, the end result of this is faster access to aid, reduce confusion and better coordination during disasters and the ability to save a greater number of lives. In this article, we describe the development of a Communication and Tracking Ontology (CTO) using the seven top-level steps as proposed in [20] to support communication and tracking activities during and after a disaster. The CTO is consisted of ten high-level classes to describe the ten different disaster-relief inter-related sub-domains.

For future research, a distributed multi-agent based Communication and Tracking System (CTS) will be built using an open source framework for mobile devices, i.e. IONIC (Ionic: Advanced HTML5 Hybrid Mobile App Framework). Based on the above ontology, simulations and trials of CTO and CTS involving real users will be carried out based on real-world emergency response scenarios to test the robustness and effectiveness of our proposed CTO and CTS. Separately, we are engaging the emergency response community to get their response on the above ontology and to listen to their recommendations when designing the CTS [37]. In order to ensure that the CTO will fulfill the requirement of CTS, verification and validation with experts will be conducted. The Delphi evaluation technique [38] will use as a method because it is a proven method for gathering data from respondents within their domain of expertise. This technique is also suitable for evaluating group communication which aims to achieve a convergence of opinion on specific real-world issues that suits our requirements well.

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