Emergency Alerts for all: an ontology based approach to improve accessibility in emergency alerting systems

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ABSTRACT

When a disaster occurs it is critical that emergency response information systems share a common ontology to support their disaster management alerting functions and notifications. Notifications are critical when an emergency scenario is going to happen (e.g. a typhoon approaching) so it is crucial, for emergency systems, to be able to transmit them to all kinds of recipients. An ontology was developed by investigating different sources: accessibility guidelines, emergency response systems, communication devices and technologies, taking into account the different abilities of people to react to different alarms (e.g. mobile phone vibration as an alarm for deaf people). We think that the proposed ontology addresses the information needs for sharing and integrating emergency notification messages and contents over different emergency response information systems and to be accessible under different conditions and for different kind of users.

Keywords

Concepts and Models for Crisis Ontologies, Emergency Response Information Systems, Accessibility

INTRODUCTION

Within an emergency scenario sharing information and common knowledge about types of disasters, kinds of affected entities (people, infrastructures, communications,…), measures and alerts depending on the kind of emergencies are crucial in order to reduce the number of victims or damages.

For the above reasons one of the most important role in Emergency Response Information Systems (ERIS) is played by alert notifications (Van de Walle, B. and Turoff, M., 2007).

To provide this information is relevant but not trivial since, to get an efficient communication, many systems should interoperate with each other and thus must share a common knowledge and understanding of the different terminologies and types of crisis or emergencies. Even these last two terms should have a shared definition in order

to apply the right actions for managing them (are we in a crisis scenario while an emergency is occurring, or are we already in a crisis scenario when a potential disaster or emergency situation is going to occur?).

To help in augmenting the interoperability between the different kind of systems involved in such scenarios and also among people we developed an ontology[1] called SEMA4A (Simple Emergency Alerts 4 [for] All) including concepts taken from emergency systems and control rooms but also accessibility guidelines, devices and communication technologies characteristics. The proposed ontology can be a first step in designing a common knowledge and thus we focused on one of the most critical (to our view) features of ERIS, alert notifications. The idea is to automatically adapt (by using our ontology) the alert notifications to different kind of users (elderly, disabled …) depending on the type of technologies (thus devices) they can access and considering the impact of the kind of disasters on alerts communication and infrastructures. So for instance when a fire is occurring within a work place we know that we can communicate with people by audio notifications (smoke can reduce the visibility) but also that we can use the same kind of alert for compensating disabilities, e.g. a fire in a building close to the user's flat but the user is blind.

As Tim Bernes-Lee stated (Berners-Lee, 2007): "Disaster response is much about preparedness. If much relevant data is available in RDF, when a disaster strikes, those on the ground and across the world will be able to use it to know what best to do to respond". That's why we, not only, designed and developed our ontology integrating the categories of information described above, but also using the Web Ontology Language (OWL) to maintain the codification standard and offer an interoperable knowledge platform for enabling collaboration among different ERIS.

We evaluated our ontology by using a quantitative evaluation taking into account domain experts: a SIDAR[2] expert, and an emergency management[3] expert. We employed the EvaLexon technique (Spyns, P., et al., 2005) for measuring the accuracy and coverage of our ontology over a corpus made of emergency, accessibility and media related documents as suggested by the involved domain experts.

In the next paragraph we analyse alert notifications among emergency systems, accessibility issues within the existing alert notifications and describe lacking information and common knowledge within emergency and accessibility, and so why we need an ontology to solve this problem. Then we present the proposed SEMA4A ontology, how it has been built and we show its application by presenting a use case scenario. Successively we describe the evaluation process chosen for validating the ontology. Finally we draw our conclusions on the presented approach and describe future works.

EMERGENCY AND ACCESSIBILITY

Emergencies occur all around the world, even in places where people have advanced information technologies. As Van der Walle et al. (Van de Walle, B. and Turoff, M., 2007) pointed out, in the devastations caused by Hurricane Katrina and the Indian Ocean tsunami, technologies did not notably contribute to the faster relief of the affected populations. In other words, communications were and are a major limiting factor in disaster response (Stuver, P., 2004). For this reason, ERIS are used to share public information from governmental and professional relief organizations.

The scope of this work is within the information systems used for inform people about incoming or just-occurred emergencies, called Emergency Notification Systems (ENS), which are included within ERIS.

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[1] An ontology is defined (Neches, R., Fikes, R., Finin, T., Gruber, T,. Patil, R., Senatir, T., and Swartout W. R, 1991) as a set of basic terms and relationships of a vocabulary within an area or subject, as well as the rules to combine terms and relations that extend the vocabulary.

[2] The SIDAR (Seminario Iberoamericano sobre Discapacidad y Accesibilidad en la Red, www.sidar.org), is an online community involving people with disabilities, accessibility experts and people interested in the accessibility theme.

[3] The Emergency management expert is a professional from Spanish Ministry of Internal Affairs (Dirección General de Protección Civil y Emergencias).

ENS should be able to inform all people involved in an emergency scenario about what is happening and what they should do in order to reduce the possible effects or damages. Thus, ENS are intended to deliver information to as many people as possible using different kind of technologies (Stuver, P., 2004).

In the past, accessibility was considered as the adaptation of products and services for letting people with disabilities access them. Actually, while facing an emergency situation, all people could become disabled in some sense because of the stress, lack of information, or because of an unfamiliar environment. Nowadays, accessibility refers to compensate the disadvantages or limitations, not only of people with disabilities, but also of all people; giving place to a new paradigm called "Universal Design" or "Design for All" (Dix, A., Finley, J., Abowd, G., and Beale, R., 2003).

Thus, it is important when designing a system taking into account the needs and characteristics of all people. On the contrary, innovating without taking these elements into account could be a barrier that increases exclusion and discrimination. In order to understand if existing ENS take Accessibility principles in mind, we studied the systems included in Table 1.

System	Web	Communication Type	Source	Notification	Accessibility
3n	http://www.3nonline.com/	Emergency, Situational Alarm, Alert, System Status	Phone, Web	Phone, E-mail, Pager, Fax, SMS, PDA	No
AlertFind	http://www.messageone.com/crisis-communications/	Emergency, Situational Alarm, Alert	Phone , Web	Phone, E-mail, Pager, Fax, SMS, PDA	No
Arce	https://arce.dei.inf.uc3m.es/arce_demo/	Emergency, Situational Alarm, Alert, System Status	E-mail, Web	Web pages, E-mail	No
Command Caller	http://www.voicetech.com/Command_Caller_40.htm	Emergency, Situational Alarm, Alert	Phone, E-mail, Fax	Phone, E-mail, Pager, Fax, SMS, PDA	No
RapidReach	http://www.rapidreach.com/	Emergency, Situational Alarm, Alert	Phone, Web	Phone, Pager, Fax, SMS y E-mail	No
Sahana	http://www.sahana.lk/	Emergency	Web	Web pages	No
Sigame	http://www.sigame.es/	Emergency	Web	Web pages	No
SWN	http://www.sendwordnow.com/smart_alert_service.aspx	Emergency, Situational Alarm, Alert, System Status	Phone, E-mail, SMS, Blackberry, Palm, Web	Phone, E-mail, Pagers, SMS, MMS, VoIP, Skype, Chat y PDAs	No
WAVES Alerter	http://www.madah.com/products/subpage.asp?mer_notf_sys	Emergency, Situational Alarm, Alert, System Status	Phone, Web	Phone, E-mail, Fax, PDA and TDD /TTY	Yes

Table 1. Comparative survey of Emergency Notification Systems.

After surveying the systems presented in table 1, we found out that ENS are used by private companies, schools, government offices, Red Cross, fire-fighters, police, as well as many other institutions. Services provided by these systems are almost the same, delivering notifications by phone, e-mail, websites, pagers, faxes, VoIP, SMSes and instant messengers.

Moreover, we have also taken into account the CAP (Common Alerting Protocol) 1.0 specification approved by the OASIS consortium. OASIS (http://www.oasis-open.org/home/index.php) is the Organization for the Advancement of Structured Information Standards, and CAP is an XML-based data format for interchanging warnings and emergencies between alerting technologies. The scope of the CAP is focused on defining and exchanging the different kind of alerts and types of notifications but does not take into account the different abilities of the users and does not, explicitly, model the relationships among the technologies and the kinds of emergencies. So we decided to use, directly, a structured knowledge in form of ontology to link all the dimensions of alert notifications information space (type of notification, users' abilities to react or understand the notifications, available technologies, types of emergencies and impact of the emergency on the available technologies). We found out that Waves Alerter was the only system which provided accessible notifications; in particular for people with auditory deficiencies using

TDD/TTY[4], but this technology was old and non-standard. Therefore, even if ENS are intended to inform people about an emergency, we discovered that these systems do not provide notifications considering people's profiles and preferences. This can be done by providing ENS with a model or base of knowledge (an ontology in our case) that would reflect this information (users' profile and preferences), as well as information related to accessibility, media and emergencies providing effective and customized emergency notifications.

THE PROPOSED ONTOLOGY

Designing and developing ontologies is a complex task, furthermore when creating ontologies it is necessary that people evaluate it in order to determine whether concepts and relationships included are accurate. Having this in mind, we developed the SEMA4A ontology, which has been created using the Web Ontology Language (OWL) as well as an OWL reasoning tool from Mindswap laboratory at Maryland University called Pellet to verify the consistency of existing classes in the ontology.

We extracted, refined, upgraded and linked information obtained from: (1) an ontology that contains concepts and relations needed to model the organization, structure and navigation of information contents; (2) an ontology that includes accessibility guidelines, user's profiles and actions that can be performed by users with different abilities. After combining these existing ontologies (including their concepts and relations into our ontology linked among them), we added another portion of the ontology by extracting information related to emergencies, notification and devices using a semi-automatic technique applied to the general purpose ontology WordNet (Miller, G., A., et al., 1990).

Ontology structure

The current version of SEMA4A includes information related to content design, accessibility guidelines, emergencies, devices and communication technologies organized in three main categories: (1) WAfA; (2) AccessOnto; (3) EMEDIA. Below we explain what information is included in each section, as well as the process followed in order to obtain this information.

WAfA

Web Authoring for Accessibility (WAfA) is an existing ontology also known as Travel Ontology because it is based on the analogy of web navigation with tourists' trips. This ontology represents concepts and relations necessary to automatically model the structural organization and navigation of web pages (Yesilada, Y, 2005) to users' profiles.

This ontology has been evaluated with real users, contains information on how to model content for being accessible, and it is codified using OWL; we extended our ontology including WAfA concepts, defining a class called WAfA that contains concepts and relations needed to model organization, structure and navigation of sites.

AccessOnto

AccessOnto in an ontology in form of an accessibility requirements repository from which it is possible to extract requirements using an accessibility knowledge base (AKB) built on user's characteristics (Masuwa-Morgan, K. and Burrellb, P, 2004). It includes guidelines from Web Accessibility Initiative, Sun Micro Systems, IBM, Microsoft, and Apple guidelines.

In our ontology we created a class called AccessOnto that contains information related to Web accessibility guidelines, users' profiles and actions that users can perform. We created this class translating information from XML (AccessOnto is codified in XML) to OWL; after this phase, we established relations that linked concepts contained in WAfA and in AccessOnto sections, as we will show in the use case section.

EMEDIA

EMEDIA (Emergency and MEDIA technologies) is the portion of the SEMA4A ontology that provides concepts and relations about emergency and media technologies. We developed it trough a semiautomatic procedure with two phases: the first phase was performed to extract new concepts and relations from WordNet (concerning emergency

[4] (Telecommunications Device for the Deaf/TeleTYpewriter) A user terminal with keyboard input and printer or display output used by the hearing and speech impaired (source: PCMag.com, *http://www.pcmag.com/*).

and media technologies); the second to integrate new information within the existing ontology (adding relations with the others portions). We applied this technique to develop and expand part of our ontology related to the emergencies and how they can affect technologies accessible to the users.

The first phase of our procedure consisted of extracting concepts and relations automatically from WordNet. The starting point was a simple set of words, related to emergency and media technologies, found in *MyFlorida.com* (The Official Portal of the State of Florida. MyFlorida.com - Taxonomy - Disasters & Emergency Information[5]) and *A Simple Taxonomy for Mobile Emergency Announcement Systems* (an article about a taxonomy developed by Ronja Addams-Moring, Markku Kekkonen and Shushan Zhao), as suggested by emergency field experts (Spanish civil protection). We proceeded, initially, retrieving these concepts in WordNet. For each meaning of each concept, WordNet gives a set of synonyms, holonyms, hypernyms, hyponyms and meronyms. Synonyms represent new concepts and others are relations that can be possibly added to the ontology. We iterated this procedure with all synonyms found as in an n-ary tree: each concept was a node with a child for each related synonym until a maximum of three levels (this threshold has been experimentally set; fewer levels will generate few terms, while more levels add terms which are not really related to our domain). For each concept we stored all meanings and relations. In this way, we obtained a new taxonomy related to emergency and media. The final phase consisted of integrating the new taxonomy in the existent ontology as a new class, EMEDIA.

Summarizing, SEMA4A counts on three basic classes: WAfA, AccessOnto and EMEDIA; including information related to concepts and relations needed to model organization, structure and navigation of information contents; accessibility guidelines, user's profiles and actions that users can perform; as well as information related to emergencies, notifications and devices. These main classes are linked with relations existing within their subclasses. The following section we provide a use case that depicts the more common relations that exist in our ontology.

Use case

In order to understand how the concepts and relationships included in SEMA4A can be used by ENS for providing accessible alerts notifications, we provide a use case.

Imagine a blind person walking alone on the streets in a city that he/she is visiting for the first time. Before going to the city, this blind person subscribed to an ENS.

Weather forecasts for the city where the blind person is touring, predict that a cyclone arrives in around 12 hours. If the ENS wants to alert the person about this approaching event, it is important that could provide significant information in a format that he/she can access. When this person subscribed to the service, he/she communicated that the media device he/she was going to carry, was a Personal Digital Assistant (PDA) with Internet connection. This person also pointed out that he/she had a special program installed in his/her device for reading the screen (screen reader) that could transform text and images into audio and/or Braille language. The ENS could use SEMA4A for alerting the blind person in an accessible way of the upcoming event taking into account his/her preferences and profile information as follows:

- From the ontology, we can derive that blindness is a visual impairment where people cannot see; we can also see that they may have difficulties using a standard mouse (or a pointing device like the pen used with PDAs); whereas it might be common that blind people use speech input and output, as well as tactile input and output (e.g. Braille line, which is a Braille display). It can be also obtained, from our ontology, that blind people could use standard keyboards, and could access information contained in sounds, as well as notice vibrations. According to the actual version of SEMA4A, blind people can access text data using a Braille line.

[5] http://www.myflorida.com/taxonomy/floridian/disasters%20&%20emergency%20information/

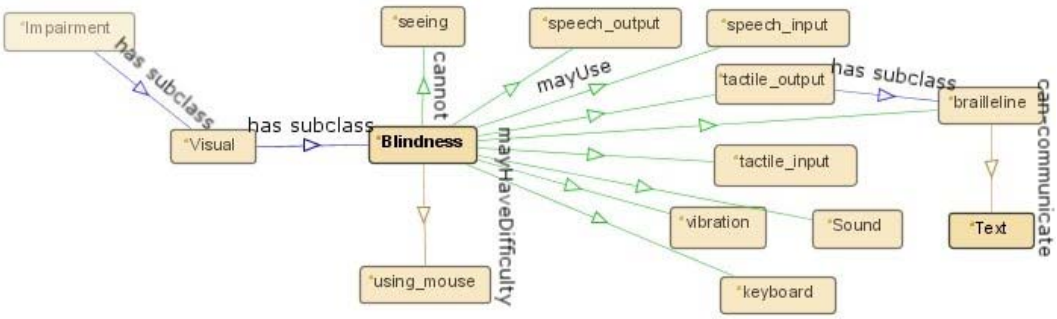

Figure 1. Definition of blindness.

- As the ENS needs to alert a blind person using a PDA with Internet Access, about an approaching cyclone, it could obtain from our ontology that PDA (Personal Digital Assistant) was a media device that could communicate information contained in figures, sounds, text, as well as vibration signals (see Figure 2). From our ontology it can also be obtained that cyclone is an emergency that could be communicated using the Internet, newspaper, TV and radio (see Figure 3). This work is at an early stage so we are not specifying here exactly how a service can derive information from our ontology; however, since it has been built mainly from XML structured information, we can adopt standard techniques for retrieving such information.

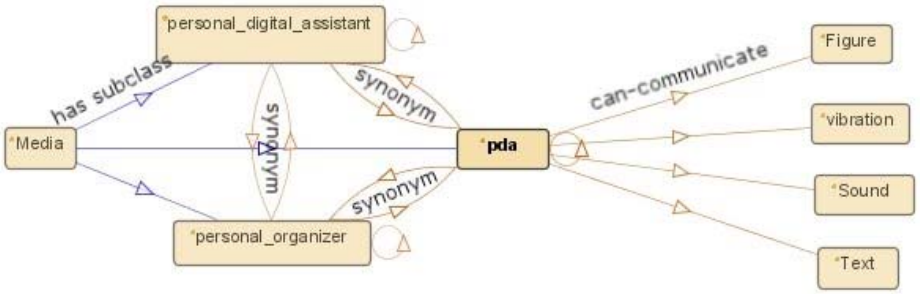

Figure 2. PDA communication features.

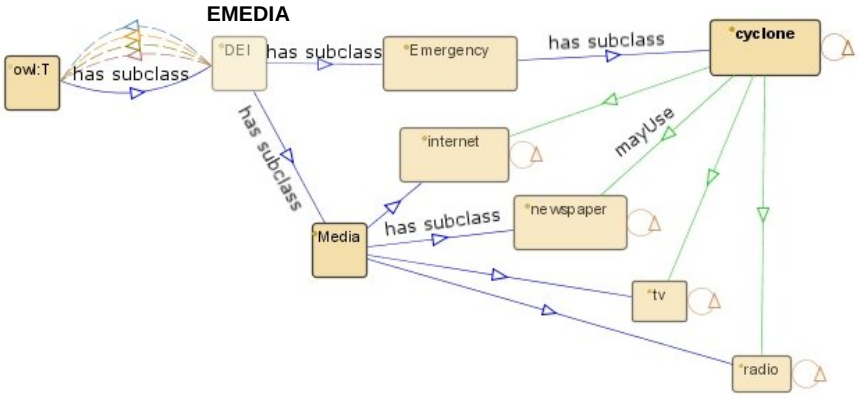

Figure 3. Cyclone and media that can be used to alert about.

- According to the user's profile and preferences, the ENS can notify information via the Internet. Having this in mind, from the ontology we know that using the Internet we can communicate employing multiple languages, text, figure, video, sound or emails.

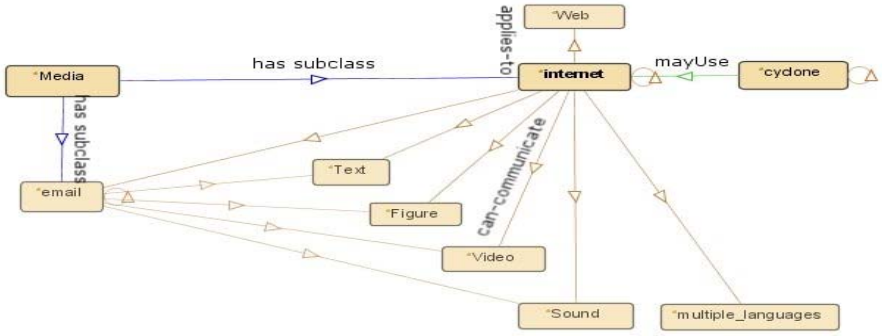

Figure 4. Internet communication capabilities.

- In order to assure that this person could access the information, SEMA4A can select to follow some guidelines from: Web Accessibility Initiative (WAI), Accessibility Quick Reference Guide, Custom Guidelines, Neuman's guidelines, as well as guidelines from IBM relative to adapt content for blindness.

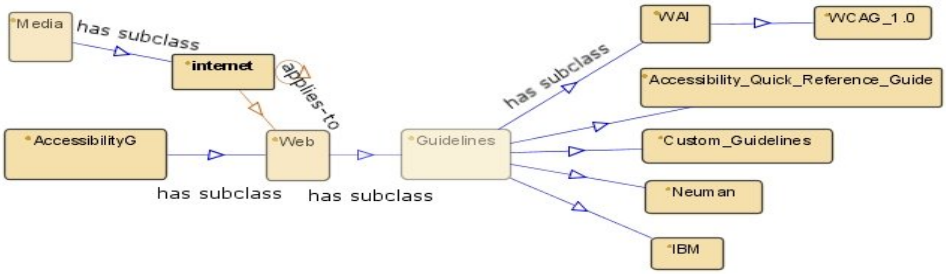

Figure 5. Web accessibility guidelines.

- Finally, SEMA4A infers Web accessibility guidelines specific for blindness for assuring that this blind person can access the cyclone alert notification over his/her PDA in order to save his/her life. For instance images descriptions (which can be read by a text-reader software) replacing graphics.

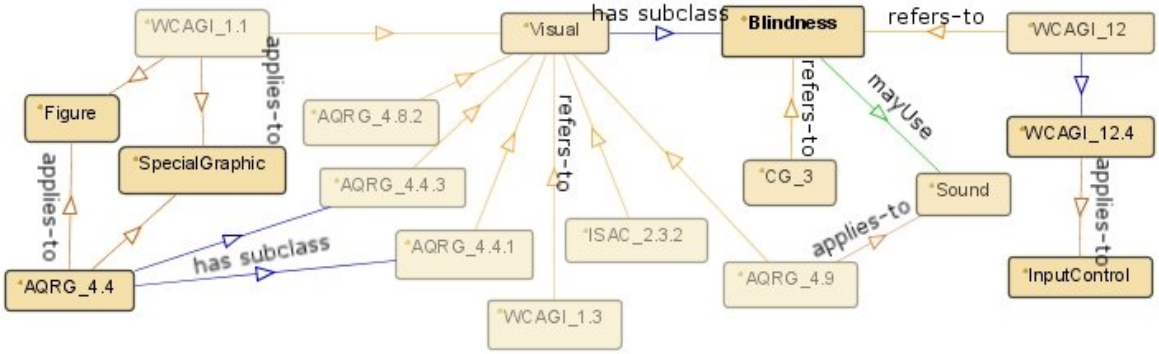

Figure 6. Guidelines for color blindness.

ONTOLOGY EVALUATION

Evaluation Criteria

There exist many different methods and techniques to validate and evaluate ontologies. We used an approach inspired by Spyns et al. (Spyns, P., Meersman, R. and Jarrar, M., 2002) based on triples extracted from the ontology

which were defined as lexons. Formally, a lexon is described as <term1 role term2>. We can say that a lexon expresses that the term1 (or head term) my have term2 (or tail term) occur in an associating role with it.

The main research hypothesis in this paper is that lexons, representing the basic binary facts expressed in natural language about the emergency notifications and accessibility domains can be extracted from the available textual sources, i.e. a corpus (see (*Hartmann J.,et al., 2004*) for a survey on miners that can be effectively used for extracting ontologies from text), but can also be found in our ontology as OWL-triples.

The considered corpus is composed by articles about emergency, accessibility and devices as suggested by the domains experts. In particular, for the *emergency* topic there are about sixty-seven article from the proceedings of the conference *ISCRAM2007* (*Intelligent Systems for crisis management)*, plus a manual developed by the North Central Texas regional government (*Know what to do. Think. Prepare. Act.*[6]) and papers on community emergency management (for example: Schafer, W.A., et. Al, 2007). For accessibility and supported devices, we considered the *Web Content Accessibility Guidelines 1.0* with W3R Recommendation of 5 May 1999 and twenty-four articles from *www.webaim.org* (*Web Accessibility in Mind*). The total number of analysed words is about three-hundred thousand for five-hundred pages.

We extracted all words from the corpus and applied a tagging procedure for the analysis of corpus texts. We analysed the input texts (the whole corpus in textual form) and tagged each word with its syntactic function (nouns, verbs, adjectives, etc.). We considered only nouns and verbs at this stage and reduced them to the root form (singular nouns and verbs at infinitive). This normalised corpus has been used to be quantitatively evaluated against lexons extracted from our ontology.

We defined a quantitative measure and a semi-automated evaluation procedure for measuring coverage and accuracy over the entire corpus. The underlying idea is inspired by Zipf's law (Zipf, G. K., 1949). It states that the frequency of the occurrence of a term is inversely proportional to its frequency class. Zipf has discovered experimentally that the more frequently a word is used, the less meaning it carries. From the Zipf law we know that the relevant domain specific concepts should be in the middle to lower frequency classes and so the lexons mined from the corpus should probably contain the relevant terms between these classes.

Coverage has been measured by counting, for each frequency class, the number of lexon terms contained in the ontology that are identical with terms from the corpus and comparing this number to the overall frequency class term count. *Accuracy* has been estimated on the basis of the coverage percentage for a selected interval of classes. We choose not using a computable precision measure here (see (Reinberger, M-L., Spyns, P., Daelemans, W. and Meersman, R., 2003) for an earlier attempt).

As the SEMA4A lexons consist of three words (two terms and one role) extracted from the domain knowledge, it is possible to investigate how much the lexons extracted from the ontology cover the corpus, and more importantly how accurate they are. Regarding the accuracy, determining exactly which frequency classes contain the terms most characteristic for a domain still depends mainly on intuition and subjective opinions. It should also be point out that no stop word list has been defined because lexons have been produced extracting nouns and verbs.

In order to produce a graphic representation (Figure 7), the highest frequency classes have been omitted (e.g., starting from class 600 we have obtained very generic terms: 'exercise' (621), 'example' (1312), 'information' (4425)). On the other end, the classes 1 to 9 are also not displayed: class 1 to 9 contained a lot of lemmas (too specific) resulting not useful like 'covenant', 'downtown', 'eastward'.

Also some non-word elements have been removed (e.g., 'jj','rb'). The frequency classes (FC) of lexons extracted respectively from the corpus and the ontology are shown below and can be categorized as follows:

- FC < 9: many non-words and/or too generally related to the domain
- 9 < FC < 350: domain related technical language
- 350 < FC < 600: general language used in a technical sense
- FC >= 600: function words and highly used general language terms

[6] http://www.knowwhat2do.com/en/pdf/KnoWhat2Do_Guide.pdf

We determined the selected area (including domain specific terms) by using the "resolving power of significant words" (Luhn, H. P., 1958) to be in the range of frequency classes 9-600. Figure 7 shows that the coverage improves with the increasing rank of the frequency class (showed until FC=300 to have a clear view of the graph). On average, the coverage ratio is 32.56%. The accuracy (i.e. the coverage percentage for the selected interval) ratio for the 9-600 intervals is 42.24%. Anyway we should say that within the 350-600 intervals the accuracy grows up to 67.1%. This phenomenon is probably due to the fact that our corpus was made of documents about the different accessibility and emergency domains but including few existing documents on both domains and that had possibly reduced the specific terms but supported more general terms used in the technical domain senses. Moreover, the EMEDIA portion of our ontology has been developed by selectively extracting terms (with a semi-automatic procedure) from Wordnet and thus is affected by some approximations, or errors.

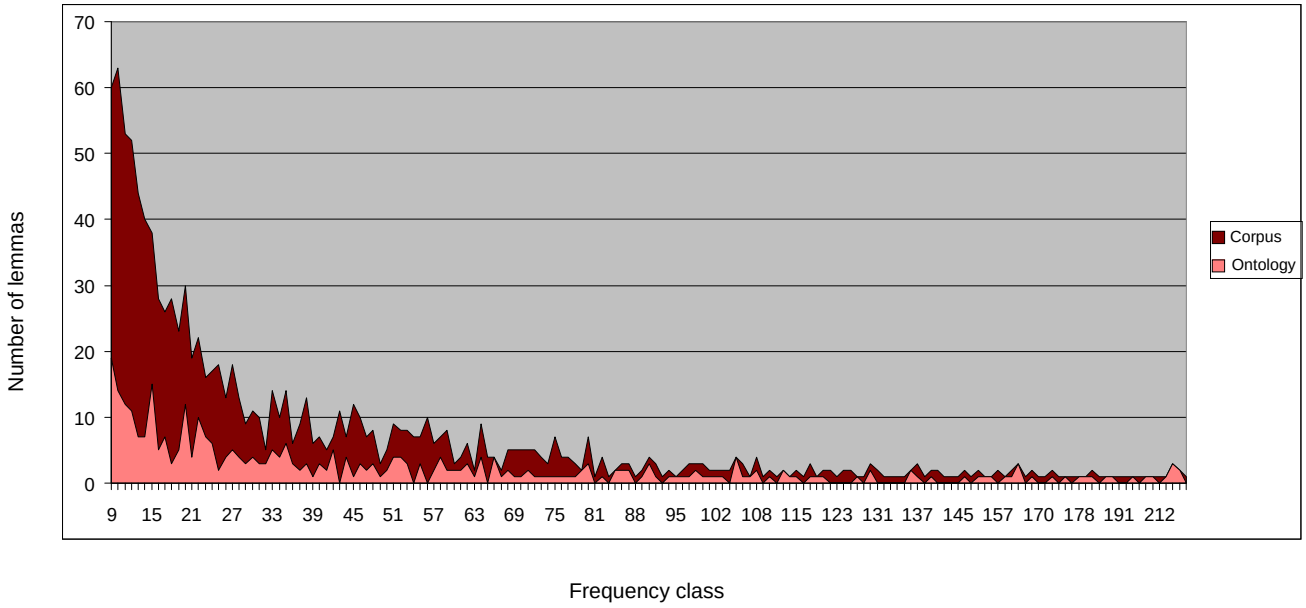

Figure 7: absolute coverage and accuracy of frequency classes of the ontology over the corpus.

CONCLUSIONS AND FUTURE WORKS

When critical events can occur people has to be informed as quick as possible and with complete and understandable information to reduce the damages or to inform about what measures can be taken for people's safety.

We showed that emergency information systems generally do not include information and knowledge about how different kind of users can be notified about an emergency; there is a lack in taking into account differences in accessing the information source (e.g. Internet or radio) or available resources depending on the cognitive and physical abilities of people. Providing accessible information within emergency response information system is crucial within such domain since it can reduce the number of victims and strongly help users when communicating emergency and critical news.

To solve this problem of communicating emergencies and critical information to different categories of users (impaired, aged …) within different kind of emergencies using different technologies, we have developed a knowledge base codified as an ontology. We have also explored accessibility and investigated on general guidelines and users' experts guidelines coded as ontologies. We selected two ontologies: WAfA, and AccessOnto considering them as the most relevant for codifying from different point of views the accessibility concepts we would like to import in emergency scenarios. We, then, developed another portion of our ontology called EMEDIA with a semi-automated technique including information on emergencies, and how they can affect technologies.

Starting from the three portions we have developed a new ontology called SEMA4A including concepts and relationships considering different users profiles and abilities in conjunction with different communication medias (EMEDIA) and usability and accessibility guidelines.

Furthermore we employed a quantitative evaluation technique measuring the coverage and accuracy of our ontology over a corpus of documents (on accessibility, devices and emergencies) suggested by domain experts. We may notice that even if we have around 30% of coverage and 40% of accuracy, the corpus is mainly separated into two topics and only few documents share the topics of accessibility and emergencies (this is exactly the lack of information we are trying to fill with our work). This originated the result of having 67.1% of accuracy when testing general terms used in a technical sense (few terms specific of both domains within the same document).

Future works include the possibility of integrating the ontology within an emergency system to test whether effective notification can be generate by an event-driven process refined by the knowledge base contained in the ontology to inform users according to their devices and abilities.

Moreover we will automate such process by developing a fine-grained level in the ontology to exactly match users' abilities with accessibility guidelines and new interactive media features (haptic interaction: touch, tactile, force-feedback, using force/resistance, texture, heat, vibration).

Finally we aim to validate our ontology within a wider audience of domain expert testing it within international organizations.

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