AN OPEN ONTOLOGY FOR OPEN SOURCE EMERGENCY RESPONSE SYSTEM

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ABSTRACT

Emergency Response and Relief Coordination Efforts are evolving to leverage the efficiencies offered by the internet in the area of real time communication among agents and stakeholders. There is widespread consensus both in the technical and ER community that to improve efficiency of response, information must be shared and web based protocols must be used [22]. In addition to known technical and non-technical obstacles that inhibit the effective and seamless coordination of operations, we identify issues that challenge the development of functional information and communication models. Recent studies in ontology engineering, and evidence from direct observations of open-source work groups in this field, point to the need for an easy to use 'open' conceptual and semantic framework, defined here broadly as 'Open Ontology' (OOnt), and a corresponding design and implementation methodology that can be referenced unambiguously and universally by developers and users of information systems designed to support ER operations.

Keywords

Open Source, Collaboration, Semantic Web, Ontology, Knowledge, Emergency Response, Emergency Management, Engineering, Standards

1. INTRODUCTION

In the last couple of years there have been world scale natural disasters of epic proportions: the tsunami of December 2005, hurricane Katrina, a massive earthquake in Pakistan, and the most recent Java Indonesia humanitarian crisis, are some examples. While natural disasters are nothing new in the history of humanity, the availability of new ICT technologies, especially the Internet and related web based applications constitute an ideal pervasive, real time and distributed platform theoretically well suited to optimize data exchange, and consequently increase the flow of information, resulting in improved coordination among emergency response and crises relief service providers. Large scale communication and coordination failures instead systematically characterize global scale ER operations [1, 2], and are largely caused by complex historical, political and cultural conflicts among people and societies that are beyond the scope of IT systems.

1.1. Goals, scope and contribution

In this paper we acknowledge that the lack of an open, easy to reference, sufficiently generic common conceptual and semantic framework for defining information exchange concepts, terminology and data formats in the event of a global, or large scale regional 'disaster' results from historical different 'views of the world' among various ER service providers, agencies and organizations, and helps to perpetrate poor communication, therefore to poor cooperation, among them – thus preventing synergies and 'network efficiencies to take place among the ER community.
The goal of this paper is primarily to raise awareness of the critical, complex and difficult to grasp issue , which is perceived as a central weakness in the sector, and as a starting point to encourage further research. As the result of direct observation of distributed and heterogeneous operating and development environments, as well as review of key research findings, the following sections attempt to define at least in part the problem set and propose steps towards integration of conceptual and semantic in standard engineering practices, but that can also suitable for open source and rapid deployment environments. Our research identifies and aligns key issues that relate to the information society at large, namely the challenges and opportunities deriving from the integration of different disciplines and fields of research. It documents and captures some of the working knowledge that is being generated

by discussions groups, and compares it to the findings and recommendation of recent research in the field of knowledge and software engineering. Ontology engineering and its widest implications are addressed by the author in relevant discussion groups and not the scope of this paper. Developing a common open ontology is an immense challenge, but an essential step towards the practical bridging of communication gaps, necessary to support the mechanisms for sharing and reusing knowledge and interoperability. This paper supports the view that by increasing the efficiency of communication, access to shared data and transparency of data network [3] synergy can take place and projects and efforts can benefit from the multiplier effect, resulting in optimization of resources and better communication that could potentially improve trust and diminish conflict. Finally we provide a summary of the state of the art it the sector, and point towards a novel 'lightweight' methodology that is being developed in future work. The main contribution, in addition to analysis described above, consists of paving the way towards an 'Open Ontology' [OOnt], by outlining a definition and tentative requirements for it. Finally, it gives an overview of the state of the art and anticipates some principles underlying an integrated methodology framework designed specifically to create and support knowledge and semantic consistency that suit dynamic and collaborative and unstructured development environments.

1.2. Problem statement

In the first analysis, we consider as generally accepted the following assumptions:

1. The Internet and Web based applications are currently not satisfactorily used in support of emergency and poverty alleviation programs, despite their immense communication potential [4]

2. Large amounts of resources are raised from multilateral agents and deployed during humanitarian crises, but there is unease in the sector as to the lack of transparency and efficacy of such programs. There is also widespread and demonstrable inefficiency in resource allocation, and inadequacy of the mechanisms to support the optimal use of such large amount of resources. [5]

3. Poor synchronization and coordination among operating agencies is aggravated by lack of semantic and conceptual interoperability, preventing synergy and multiplier effect to take place that would maximize the use of such resources. [6]

4. Lack of transparency in decision making and data flow processes aggravate lack of trust and constitute the essential condition for corruption and poor administration to take place. [5]

Considering the above scenario, there is widespread consensus that the availability of functional, flexible and reliable open source systems in principle should be preferred to proprietary ones to support transparent and efficient data flows in Web based environments, and to support the 'architectures of participation' model which in an ER context are highly desirable, yet it is not easy to fulfill the demanding requirements of sensitive and ‘life’ critical operations without applying highly structured risk reducing software development methodologies (such as SSADM), to which open source development teams are highly adverse. Following extensive literature review and active participation in related workgroups, the main problems identified can be summarized as follows:

1) The lack of a usable and open conceptual and semantic framework that can be referenced unambiguously by system developers including open source teams.

2) The lack of a lightweight and agile ontology engineering methodology with 'low' barriers to adoption.

3) The difficulty of reconciling 'critical' data and semantic integrity requirements necessary to reduce risk and ambiguity in large scale ER operations, and the unstructured open source development approach, also known as 'bazaar style', characterized by rapid, extreme and chaotic development patterns.

2. WHAT IS AN OPEN ONTOLOGY?

Many authors give different definitions for 'Ontology', depending on the context and goals that the definition, as well as the ontology, needs to serve. John Sowa of IBM often says that ‘the word ontology is very popular nowadays but nobody really understands it’. A useful overview is provided by Mizoguchi [8], while for technical references, a good must-read work is the Ontology Metamodel [9]. After extensive literature review and intense exchanges with experts, for the purpose of this paper we purport that 'An Ontology is the highest level of abstraction of the conceptual and semantic representation in a given knowledge domain.' [10] Particularly in Web based environments, an ontology delimits the boundary of the system's knowledge and functional domain, and serves as conceptual and semantic reference for software development. In practical terms, entities and attributes, classes, objects and properties, as well as data models, data schemas, metadata and vocabularies and their extensions, when 'normalized' all contain information that models a view of the world, for the purpose of a given system. This mean that no logical system can exist without clear reference to an ontology, and that the ontology must be clearly reflected in all aspects of the system's design and implementation. [various]

A clear representation of the correspondence between the data model and the metadata is provided by Kitamura, Washio, Koji, Mizoguchi [7]

Class	
entity	Physical entity
function	Interpretation of behavior under a goal
way	Way of function achievement: conceptualization of the principle essential to the achievement of the parent (goal) function by the sub(part)-functions

Property			
Name	Domain	Range	
agent	*function*	*entity*	*Function* is achieved (performed) by the *entity*
part_function	*function*	*function*	*Function* in the Domain (Subject) is decomposed into that in Range (Object)
possible_way	*function*	*way*	*Function* can be achieved by the *way*
method_ function	*way*	*function*	*Way* contains *function* as sub(part)-functions to achieve the goal (whole) function

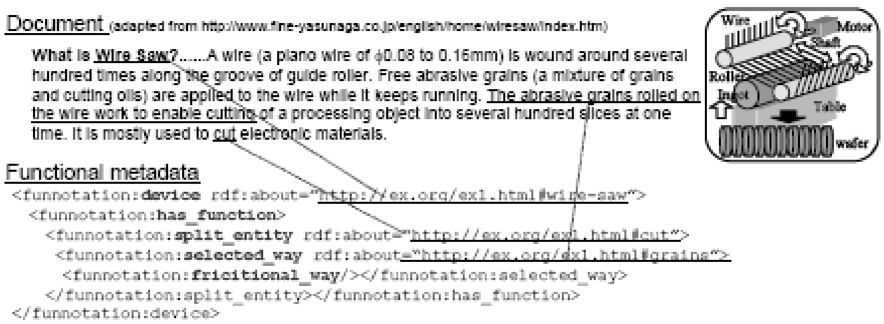


Fig. 4. Examples of metadata for a document of a wire-saw

Towards Ontologies of Functionality and Semantic Annotation for Technical Knowledge Management [7]

With the term 'open ontology' we refer to a given set of agreed terms, both in terms of conceptualization and semantic formalization, that has been developed based on public consultation, that embodies and represents and synthesizes all available, valid knowledge that is deemed to pertain to a given domain, and is necessary to fulfill a given functional requirement. An Oont must be publicly documented, and accessible and with minimal barriers to adoption. Among the barrier to adoption for Ontology, research identifies [11] not only different linguistic, conceptual and cultural differences, but also knowledge and point of view differences that set apart academics – who generally develop ontologies and related tools and methodologies – from experts – who understand lingo and the dynamics - system developers – programmers, systems designers and end users at large. By 'open' we indicate 'perfectly flexible', extensible, and with adaptive boundaries that dynamically adjust to constantly changing parameters [12] and also 'open as opposed to 'closed', whereby an ontology is developed internally by an organization or consortium, with the purpose of imposing a single view of the world, without a public consultation process and no public deliverable is available that can be used and referenced as guidelines by system developers for the purpose of third party integration.

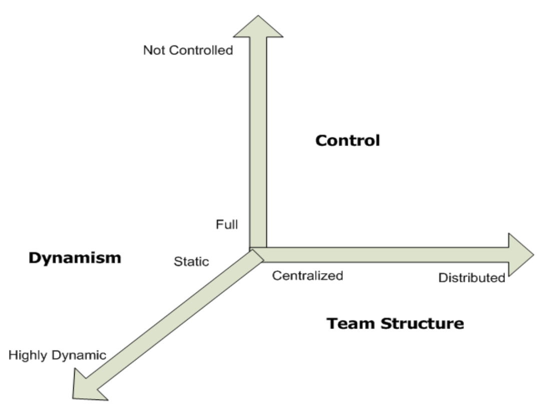
Research [13] confirms that there are tangible barriers to use and adoption of ontology modeling tools and techniques, in particular the absence of a clear set of structured deliverables, the lack of a structured methodology for ontology engineering. Among the barriers to entry is also an extremely high level of technical expertise required to decode and apply guidelines.

2.1. Open Means Collaborative: Dynamics and Requirements

'Collaboration' is happening everywhere, thanks mainly to the Internet and 'Web 2.0' type tools that are populating desktops, although few organisational policies and practices are keeping up to speed in leveraging the potential of collaboration. Open source communities have been early adopters of online collaboration environments, although increased abstraction and complexity and increased geographical and cultural distribution challenges effective online cooperation even among open source communities. It is argued by some that t 'Open source' is not suitable to Emergency Response projects, yet initiatives spontaneously emerged during recent disasters [16] point towards the emergence of a possible model, that needs to be defined and refined before it can be evaluated and tested.

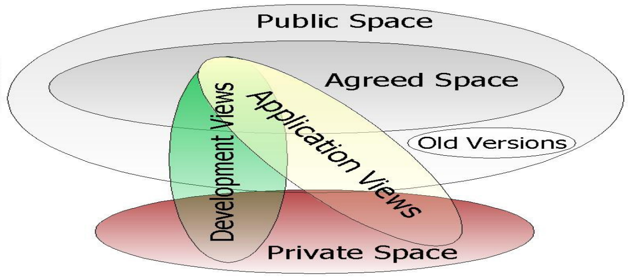
An important emerging research area is 'Collaborative ontology development'. As put by Farrukh Najmi, Engineer at Sun, "Ontologies often need to be developed collaboratively by a group of geographically dispersed Domain Experts within a certain domain. Each Domain Expert builds a different sub-graph (network) of the ontology, may review the ontology sub-graphs produced by others, may edit ontology sub-graphs that they or another Domain Expert created with appropriate access control ". Plural and Collaborative ontology development models are emerging, and among the core attributes identified is the flexibility in incorporating new concepts and/or languages [14]. A wealth of related work is becoming available to witness the shift towards open collaborative environments. Pinto [15] describes collaborative ontology environments as:

- **Highly distributed:** Anyone can contribute more knowledge.
- **Highly dynamic:** Several contributors may be changing knowledge at the same time, with high change rates.
- **Uncontrolled:** There is no control over what information is added, and the quality and reliability of that information. In this case, there will be a lot of noise (positive and negative contributions), and not everybody contributing to the ontology will be focused on the same task or have the same purpose.



(Pinto and Martins 2002)

Several new noteworthy models of collaborative ontology production are being put forward that tackle the requirement arising from the complexities of representing and reflecting distributed views in 'simultaneous multiple worlds'. Among them we study and find particularly applicable to the highly international and distributed domain of Emergency Management, innovative models of ontologies such as 'Packet ontologies' [17] and 'View-based Methodology ' [18]



View-based Methodology

3. GENERIC REQUIREMENTS FOR AN OPEN ONTOLOGY

Referring directly to a) the nature of the collaborative environments that is typical of large concerted efforts during emergency situations and b) the emergence of novel ontology engineering methods, it is becoming mandatory to make a clear case for an 'Open Ontology' so that research and relevant efforts can be started towards an OOnt for EM. There is consensus among the international community that specifications, guidelines, references and documentation for an EROo (Emergency Response Open Ontology) should be implementation and platform independent, and should be designed for adoption of a variety of user roles, without special advanced technology or knowledge skills. Usability, accessibility, and implementation independence and low barriers to adoption are overall requirements for an open, collaborative ontology for the ER sector. In particular, given the current global and culturally diverse landscape, usability and 'good design', as specified by Norman, are paramount also to engineering development and methodologies to create working documents, tools and deliverables that can actually be referenced by distributed and heterogeneous teams of developers and users alike. Creating an ontology is a much more articulate exercise than just opening up an ontology editor and creating an OWL or a RDF schema of your chosen reality subset. It entails probing axioms and assumptions of any given view of the world, eliciting and validating relevant knowledge, making choices regarding goals, functions, boundaries, terms and definitions, and creating a clear system documentation including ER and DFD, LD. Then opening up the process for all the relevant stakeholders and communities of developers and users, and creating sets of documents and guidelines that can be easily referenced and used irrespective of role, level of domain knowledge and IT expertise.

In summary, we propose that an initial outline of requirement for an Open Ontology that can be referenced universally, including by open source teams, should have the following characteristics.

3.1. Generic top level requirements for an Oont

- it should declare what high level knowledge (upper level ontology) it references,
- it should declare what kind of reasoning/inference supports/it is based on,
- it should support queries via natural language as well as machine language,
- it should be visible, searchable and support queries via a Web based interface that does not require any plug-in and API for users to download,
- It should allow users to provide feedback that should be taken into account in subsequent iterations,
- it should be documented and annotated, and available in different file formats including Open Document,
- it should be 'easy to understand' by generic users without specialized skills and guidelines should be provided as how it can be used to support development practices,
- it should include instructions on how to relate such 'high level knowledge' to standard knowledge representation artifacts used in software and systems engineering, such as entities, attributes, classes, objects, properties, sub-properties, values and relationships,

- It should be implementation independent; this means not only usable by OWL/DAML model but also reusable by alternative ontology languages

- it should support one view of the world if required, and allow for simultaneous multiple views, meaning that it should aim to be perfectly elastic, flexible and adaptable,

- it should take into account language and cultural diversity, and corresponding different value systems and knowledge representation requirements,

- it should be supported by tutorials and educational materials at different levels of specialization.

The requirements above need further discussion and a public consultation. They have received positive feedback from both the ontology and the ER community.

In addition to the generic requirements above, any conventional requirements should be specified depending on the target system and goals.

4. CASE STUDY: SAHANA.LK

Operations are increasingly distributed, and human resources are distributed accordingly. This is true not only of ER teams – but also of developers and IT professionals supporting ICT deployments. Similar characteristics as described above are observed in the development of Sahana.lk.

The 'official' Sahana.lk history is available online. [19] This effort is singular in that it has survived the momentary emergency and has lasted and evolved, unlike other projects which emerged in parallel, (Peoplefinder, Katrina 2005) served a temporary function and then died off, probably thanks to support of its many contributors, in addition to the enthusiasm of developers and surrounding interest group. Sahana has recently started to accept that in order to evolve from prototype stage it needs to apply more consistent internal documentation and processes – despite this being contrary to the original 'extreme development' culture, it must take steps towards mapping its conceptual domain and towards evolving a consistent semantic layer. But the development team is highly unstructured and does not work in any particular order, and only partly speaks the same language. As a modular architecture being developed by multiple teams, Sahana provides an opportunity to carry out an analysis of some of the internal group dynamics showing clearly some of the challenges that the open source community at large must face and resolve, to reduce the ongoing risk of critical failure in sensitive context, and to withstand and address increasing pressures and expectations that are placed on large scale critical systems, which Sahana aims to be.

4.1. The Nature of the Bazaar:

Sahana is a good example of the bazaar environment, where some of the following environmental and behavioral manifestations can be observed:

- ✓ Developers come from different linguistic and cultural backgrounds

- ✓ Have different ideas as to what the system and its modules should do, and how

- ✓ Extensive and prolonged discussions are commonplace as to the meaning and interpretations of concepts and terms, both in the technical domain as well as in the emergency management domain

- ✓ Functionalities are generally developed based on notional requirements analysis and informal communication with potential users (no structured Knowledge Acquisition Technique is applied).

- ✓ Programmers are experienced and dedicated, yet have different degrees of commitment, as well as competence in English grammar (working language) and domain expertise

- ✓ Inconsistent or obscure use of technical documentation to support development

- ✓ Lack of user documentation

- ✓ Communication with domain experts happens mainly via mailing list and email exchange; no formal user profiling method is applied
- ✓ Different team members have different degrees of expertise in different domains, as well as obviously different opinions
- ✓ No formal software engineering methodology is adopted (structured methods are proven to systematically reduce risks of failures caused by inconsistencies in the design)
- ✓ Developers create and deploy modules 'as they see fit' and there is no decision support process or workflow in place – yet – (intended as a structured process accepted and followed consistently by all developers) to be used as 'guidelines' where each module can cross reference at least in principle the underlying data models and design of other modules
- ✓ Ontology and metadata architecture, and controlled vocabulary, are regarded as 'non technical' and 'non priority' (although this is changing at the time of writing)
- ✓ Entities and functions and naming conventions across different modules are duplicated, ambiguous, inexact and sometimes illogical
- ✓ There is no consistent high level documentation (ER diagrams, data flows) available to describe the overall system architecture and functionality
- ✓ There is limited documentation available, as above, for each module
- ✓ The limited available documentation [logical diagrams] show inconsistent use of terminology in the conceptual representation of the system components and duplication and ambiguity in the data model, pointing to possible further data and conceptual normalization required
- ✓ XML schema and corresponding metadata sets cannot be easily inferred, designed and implemented because the data is inconsistent and data model not visible

The above findings point to possible internal interoperability challenges among different Sahana modules, and consequent challenges in achieving external integration with other systems on the web to leverage SOA environments. Despite the uncertainties caused by the conditions above, good work is being produced, and adoption is being pushed through, despite the absence of user feedback. Lack of conceptual and semantic consistency, however, and lack of a structured development methodology, results in limited referential and model integrity, that inhibits user confidence and system reliability. The above conditions, combined, contribute to recurrent lack of consistency, that becomes repeatedly evident during ongoing opinion exchanges (displaced person, evacuee, beneficiary, missing person, are all used sometimes interchangeably – stock, supply, intake, donation most of the time mean the same thing – same for input, data, information, as well as many other terms that at the moment are not better defined but that are represented by the system as different entities creating inconsistent data flows).

Model inconsistencies cause disappointment when the system falls short of its expectations (Pakistan,, 2005). It is interesting to see how lack of conceptual and semantic integrity is directly reflected in weak data, model and referential integrity. If the case for ‘open source’ must be sustained, as many believe, then the challenge at hand now is not only to identify appropriate conceptual and semantic sets of references that are both practical to implement on a large scale, as well as acceptable to a wide diverse community of users. It is also to reconcile the freedom, flexibility and organic mindset and modus operandi of open source culture with the rigorous and systematic approach of structured software engineering methodologies.

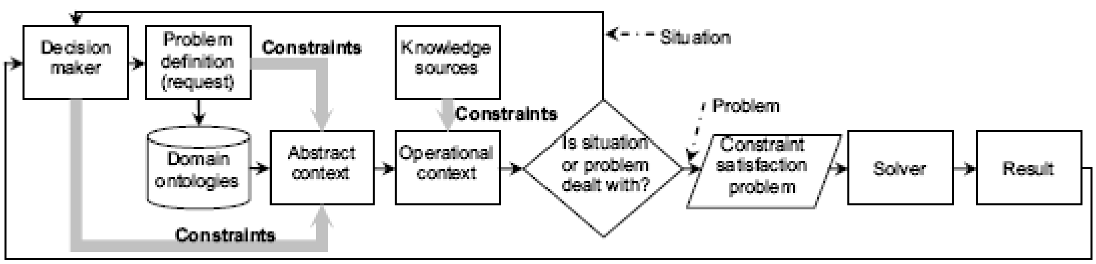
5.0 STATE OF THE ART AND FUTURE WORK

At the time of writing, no single global 'open source' initiative has been launched to address the issues above, and to satisfy openness, adaptability, flexibility requirements , and that can also provide sufficiently stable and robust Web based software to fulfill the demanding role of open source emergency management software. Given the challenges faced both by the proprietary IT industry and by the Open Source community, we perceive there is ample scope for cooperation and that Open Source Emergency Management Systems can and must be pursued, and made robust.

Current industry efforts to date tend largely to be a) vendor centric – whereby the focus is ensure standards and compatibility are taken up by vendors and b) US centric, where the majority of the promoters of initiatives in this sector tend to be initiated and promoted by US citizens and corporations. We perceive the participatory role of developing open source ontology requirements, methods as well as implementation tools may help create a balance and a wider geographical and cultural spread in the sector. Below just a small selection of leading sector wide initiatives and projects that we consider state of the art in our sector, and that we must reference and synch up with in future work.

Knowledge Logistics

Smirnov et al [6] writes "An efficient knowledge sharing between multiple participating parties is required to provide for situation awareness and consequently to manage any coalition-based operation other than war (OOTW) in the network-centric environment. It is necessary that the right knowledge from distributed sources is integrated and transferred to the right person within the right context at the right time to the right purpose. The aggregate of these interrelated activities is referred to as knowledge logistics (KL)."



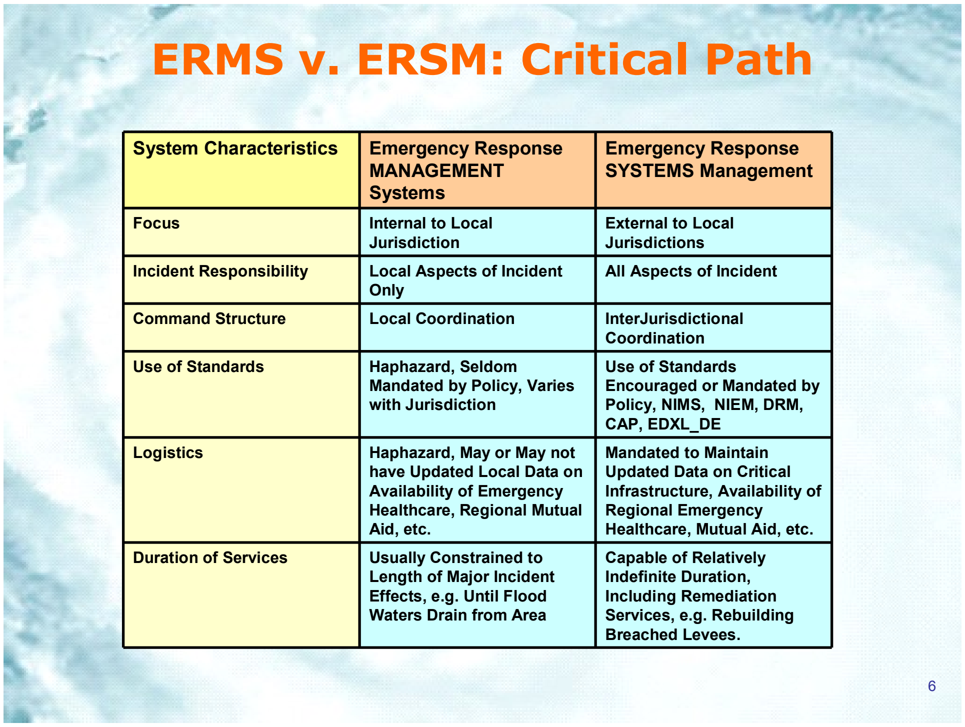
Common alerting protocol (CAP)

A CAP was defined, but there is limited evidence as to its successful adoption implementation and applications in recent emergencies.

edxML and OASIS Emergency TC

Oasis is devoted to developing common standards also in the emergency sector. There is however some feeling that although the standards are public and will eventually be accessible, that there is limited participation from the open source community, and large participation from vendors, and that standards tend to be imposed as 'top down', and there is no sufficient early community involvement is contributing to their evolution**.** This feeling was partly confirmed by a commentary by Rex Brooks [23], during the recent Ontolog Conference Call 'Ontology Applications in Emergency Response' [22], who admits 'we should have done some things earlier, but we are learning from our mistakes'. At the time of writing, the TC (Technical Committee) [23] is working on Emergency Data Exchange Language Resource Messaging Specification v1.0, and are aiming for spring 60-day Public Review [25]**.** Contributions proposed in this paper, informally discussed in private emails with Oasis was welcomed and received encouragement.

Emergency Management Information Systems Vs Emergency Response Systems Management



ERMS v. ERSM: Critical Path

System Characteristics	Emergency Response MANAGEMENT Systems	Emergency Response SYSTEMS Management
Focus	Internal to Local Jurisdiction	External to Local Jurisdictions
Incident Responsibility	Local Aspects of Incident Only	All Aspects of Incident
Command Structure	Local Coordination	InterJurisdictional Coordination
Use of Standards	Haphazard, Seldom Mandated by Policy, Varies with Jurisdiction	Use of Standards Encouraged or Mandated by Policy, NIMS, NIEM, DRM, CAP, EDXL_DE
Logistics	Haphazard, May or May not have Updated Local Data on Availability of Emergency Healthcare, Regional Mutual Aid, etc.	Mandated to Maintain Updated Data on Critical Infrastructure, Availability of Regional Emergency Healthcare, Mutual Aid, etc.
Duration of Services	Usually Constrained to Length of Major Incident Effects, e.g. Until Flood Waters Drain from Area	Capable of Relatively Indefinite Duration, Including Remediation Services, e.g. Rebuilding Breached Levees.

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Rex Brooks of OASIS distinguishes between the two definitions above as follows:

Emergency Response Management Systems

- Single System-Centered
- Coordinates Only when Required & Not Well
- Ad Hoc with Jurisdictional Conflict & Confusion

Emergency Response Systems Management

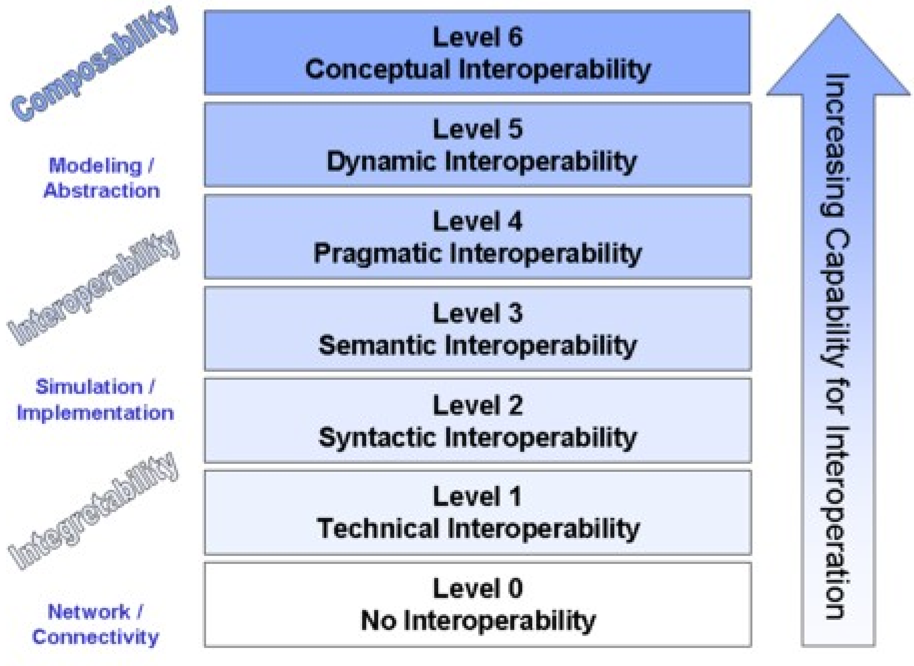
- Evolving Slowly, by Region, e.g. Association of Bay Area Governments (ABAG)
- Mandated by DHS' National Incident Management System (NIMS), National Information Exchange Model (NIEM), Federal Enterprise Architecture (FEA) Data Reference Model Across Agencies

Situation Awareness Ontology

Kenneth Baclawski, Associate Professor, College of Computer and Information Science, Northeastern University (Boston, Massachusetts, US) is working on : Achieving situation awareness of emergency response teams, which involves on situation awareness ontology (SWO) and an 'information fusion' model.

Emergency Interoperability Consortium

The Emergency Interoperability Consortium (EIC) was launched in October 2002 to address our nation's critical lack of valid interoperability standards for emergency and incident management. It is coordinating efforts with OASIS, and it is perceived as 'U.S. Centric'.



Levels of Conceptual Interoperability
Andreas Tolk, Researcher at Old Dominion University, identifies LCIM – besides being now applied in various domains outside Modeling & Simulation, where it originated –as the introduction of the several aspects of interoperation between systems: the lower layers ensure 'integratability', the middle layers contribute to interoperability: the higher levels finally address 'composability': models and abstractions, the constraints and assumptions underlying the model (which ultimately leads to the ontology). [21]

Resilience of Emergency Response Systems

Kanno and Furuta of the School of Engineering at the University of Tokyo have analyzed and modeled Emergency Response from the point of view of 'resilience' [24]. An emergency response system (ERS) is an example of resilience engineering, they say, even though it is neither a single entity or technological system nor an organization with operational activities. They model an ERS and evaluate its efficiency, reliability, and resilience/brittleness as well as typical organizational behaviors during emergency responses.

5.1 future work: integrated methodology

According to our findings, we acknowledge that the challenge is enormous. No single existing methodology, and no single discipline can exhaust the requirements and support the analysis and processes referred to above. We therefore propose the adoption of a novel approach , nicknamed 'Just enough Ontology Engineering' that integrates different approaches and techniques which address some of the shortcomings in the sector cause by the lack of suitable methodological approaches [11] and [13].

Our proposed methodology, presented and discussed more extensively in related papers,

a) leverages the potential of collaborative environments

b) offers the shared benefits of open source software and philosophy

c) integrates and leverage the benefits offered by different, complementary engineering disciplines and methodologies

Conclusion

This paper analyses and brings to the light some core issues that lie at the heart of intelligent systems and Emergency Management, in particular relating to open source projects. It provides an analysis of some of the stumbling blocks that slow down progress in this area requiring urgent developments, according to current research. We identify and propose the novel concept of 'open ontology', compiling a catalog of real life situations and problems that occur during open source development that an ontology aims to at least in part solve. Finally we provide an overview of the state of the art in the sector, and anticipate details of our lightweight methodology for integrating different disciplines and methodologies in order for progress to happen in this area.

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