IEICE TRANS. INF. & SYST., VOL.E101–D, NO.1 JANUARY 2018

PAPER Special Section on Semantic Web and Linked Data

An Ontological Model for Fire Emergency Situations

Kattiuscia BITENCOURT[†a)], **Frederico ARAÚJO DURÃO**[†b)], **Manoel MENDONÇA**[†c)], ***Nonmembers***, ***and*** **Lassion LAIQUE BOMFIM DE SOUZA SANTANA**[†d)], ***Member***

SUMMARY The emergency response process is quite complex since there is a wide variety of elements to be evaluated for taking decisions. Uncertainties generated by subjectivity and imprecision affect the safety and effectiveness of actions. The aim of this paper is to develop an ontology for emergency response protocols, in particular, to fires in buildings. This developed ontology supports the knowledge sharing, evaluation and review of the protocols used, contributing to the tactical and strategic planning of organizations. The construction of the ontology was based on the methodology *Methontology*. The domain specification and conceptualization were based in qualitative research, in which were evaluated 131 terms with definitions, of which 85 were approved by specialists. From there, in the *Protégé* tool, the domain's taxonomy and the axioms were created. The specialists validated the ontology using the assessment by human approach (taxonomy, application and structure). Thus, a sustainable ontology model to the rescue tactical phase was ensured.

key words: *emergency response, ontology, conceptual model, knowledge representation, fire*

1. Introduction

Emergency and disaster events are very complex and dynamic situations and any delay in the response may put many lives at risk. According to the *Federal Emergency Management Agency* (*FEMA*), emergency is every incident, natural (hurricanes, windstorms and volcanic eruptions) or man made (terrorism, fire and explosion) which requires a response action to protect life or property [1]. The damages caused in such situations are unmeasurable and vary according to the incident scenario. To some extent the consequences can influence the mental status, socioeconomic, political and cultural life of the affected area. In Brazil, three classic examples of unprepared rescue plan are fire in the Andraus building (Sao Paulo - 1972) which killed 16 people and injured 330, fire in the Joelma building (Sao Paulo - 1974) with more than 180 deaths and the most recent, fire in the Kiss night club (Rio Grande do Sul - 2013) which culminated in the death of 242 people [2], [3].

The response actions of fire incidents should be timely accurate and communication problems should never take place at no means. Teams selection, identification of victims severity are operations that require quick response. In addition, different rescue organizations such as Police and Fire Fighters are expected to follow or understand same emergency protocols respecting their particularities.

The lack of important communication assets for an efficient emergency response, such as clear command structure, standardization of emergencies response protocols and common terminology among the organizations, motivated the construction of ontologies aimed to support standardization of documentation for response protocols. Thus, ontologies are very useful to facilitate sharing and reuse of information [4]–[6].

The proposal of this work is to help in the standardization and sharing of response protocols of fire in buildings, through the construction of a domain ontology called *EmergencyFire*. We provide a semantic vocabulary necessary for domain applications to automatically reason through inferences. We raised a wide vocabulary from two corporations and build an ontology that was assessed by experts. In this way we expect that *EmergencyFire* facilitates sharing and integration of information, provide interoperability between people and systems, reduce occurrences of false compliances and improve response time in emergencies.

This paper is structured as follows: Sect. 2 presents the related works, Sect. 3 presents the construction process of the *EmergencyFire* (specification, conceptualization, formalization/implementation), Sect. 4 presents the ana-lysis and evaluation process, Sect. 5 presents an example of the applicability of the ontology and Sect. 6 concludes the work.

2. Related Work

In the literature many authors have proposed ontologies for emergency situations. *DIRES* is an ontology to describe emergency situations and the main factors associated with response activities to an incident. This ontology define terms based on predefined questions such as *incident* (what happened?), *operations* (which can be done?), *people* and *organizations* (who are involved and can take action?), *resources* (what resources are needed?), *time* and *place* (when and where?) [7]. *EMERGEL* (2013-2015) is an ontology core which contains the common knowledge and concepts related to emergency situations and the parties involved in a crisis situation. This ontology uses the Simple Knowledge Organization System (SKOS) to easily capture collections, subordinate concepts and hierarchies [8].

Manuscript received January 26, 2017.
Manuscript revised June 27, 2017.
Manuscript publicized September 15, 2017.
[†]The authors are with Federal University of Bahia, Brazil.
a) E-mail: kattiusciafb@dcc.ufba.br
b) E-mail: freddurao@dcc.ufba.br
c) E-mail: manoel.mendonca@ufba.br
d) E-mail: lassionlaique@dcc.ufba.br
DOI: 10.1587/transinf.2017SWP0003

We did not use the *DIRES* and *EMERGEL* ontologies because they do not have proper concepts addressing the context of fire emergency situations, which is the current focus of our proposal. Many concepts such as *combustion*, *response action*, *protocol*, *fire*, etc, were missing in those ontologies. The description of the very few classes in common (e.g. *organization*, *vehicle*, *event* and *incident*)were a little biased to the context of each ontology making them very difficult to be effectively reused in our target domain. In addition, we noticed many other classes with very technical terms related to unknown third party systems associated with particular European Projects. Although the aforementioned reasons, this does not prevent us, as a future work, to carry out a joint work in order to merge both ontologies in a single and enriched one.

EDXL-Rescuer (2014-2016) is an ontology from the project *Rescuer* (*Reliable and Smart Crowdsourcing Solution for Emergency and Crisis Management*). This project uses crowdsourcing to support industrial parks and security forces during an emergency situation. The *EDXL-Rescuer* is a conceptual model based on *EDXL* (*Emergency Data Exchange Language*), which aims interoperability between legacy systems [9].

The *EDXL-RESCUER* was not used because its focus relies solely on exchanging messages during an emergency situation rather than the procedures and actions taken in such a scenario. We observed a considerable lack of specific concepts that alternatively are addressed in our ontology. The other reason why concepts from *EDXL-RESCUER* were not used was that during the development of our ontology the *EDXL* was still a working progress without any formal evaluation. However, we are encouraged to extend our onto-logy with important concepts covered by *EDXL* as a future work.

The ontologies *EMERGEL*, *DIRES* and *EDXL-Rescuer* were created in order to solve semantic interoperability problems between systems. They deal with generic terms related to emergencies (*emergency*, *emergency type*, *involved elements*, *resources*, *organizations*, *risk*), focusing on taxonomy, concepts and relationships. *EmergencyFire*, in addition, comes to specify concepts like *fire*, *fire class*, *type of occupation of the building*, *combustion*, among others. This ontology is a knowledge base focused on emergency situations of fire in buildings. Thus, the referenced works and their documentation were used only as reference for verification of thematic approaches in order to assist in closing scope and conceptualization of the generic terms.

The *ONTOEMERGE* (2010-2013), an ontology developed by UFRJ along with University of Valencia, has the purpose of supporting variability solutions for emergency plans [10]. Likewise, the ONTOMERGE does not contain very important concepts addressed in the context of this proposal. Although some generic potential concepts were found such as *climatic condition*, *incident*, *emergency*, *organization*, *resource*, *event*, among others. However, we opted for not using them due to the fact that no evaluation on that terms had been performed to ensure their semantic accuracy. Nevertheless, upon a major evaluation of *ONTOMERGE*, we feel encouraged to extend our work with classes from that ontology as a future work.

Besides the cited works, there are others such as: i) the *OntoFire* which is an ontology-based geo-portal about wildfires than includes several concepts such as vegetation, climate and fire, in order to describe the semantic context of wildfires and their associated risks [11] and ii) the EDXL which is a suite of XML-based emergency terms to standar-dize terms for message exchanges during emergencies (it was developed and made available by OASIS in 2006) [9]. Some technologies that support emergency management such as the *SOS193* in which the goal is to guide the population in emergency situations [12] and RiskManager which includes solutions for emergency response and dispatch, intelligence, risk management and governance in order to support emergency management [13].

3. EmergencyFire: An Ontology for Fire Emergency Situations

Part of this work was presented superficially in a short paper entitled "EmergencyFire: An Ontology for Fire Emergency Situations" [14], in which the major focus was on the methodological approach used. After that preliminary publication, the work was continued and a proper evaluation with specialist was carried out. Some changes include: the class *Vehicle* is no longer a subclass of the class *MaterialResource*, some individual such as *EnteringPlace*, *ProtectingVictims* and *ClearEscapeRoute* have become subclasses of the class *ResponseAction*, and the class *TacticalOperation* was changed to *CarePhase*. The current work therefore incorporates substantial changes in both focus and content.

The process of building *EmergencyFire* was based on the ontology development methodology called *Methontology* [15]. This methodology was chosen because it is widely applied and provide several elements to support ontology development such as specification, knowledge acquisition, conceptualization, implementation and others. The ontology development took four main steps: i) specification, ii) conceptualization, iii) formalization/implementation and iv) evaluation.

For the specification, domain conceptual modeling and evaluation we were used the qualitative research approach and for the formalization/implementation we were used the *Protégé* tool [16]. The methods and instruments (interviews, questionnaires and documentary analysis) of the qualitative research approach [17], [18] used were essential to understand the domain and its relevance, lock scope, collecting terms, their relationships, definitions and rules. The data collected through qualitative research are descriptive, depicting the largest possible number of elements actually studied [18].

The study was conducted within the Military Department of Firefighters of Bahia, Brazil, because of the ease access to the experts (*http://www.cbm.ba.gov.br/*). This organization is directly responsible for fire fighting, search and

Table 1 Competency questions defined.

	Competency questions
1.	How to identify a fire incident in a Building? What is the form of communication?
2.	What is the emergency scenario?
	2.1. What is the color of the smoke?
	2.2. What is the fire class?
	2.3. What is the climatic condition?
	2.4. What is the direction of the wind?
	2.5. What is the escape route?
	2.6. What is the structural collapse in the building (crack or fissure)?
	2.7. What is the occupation type of the building (commercial, residential, industrial)?
	2.8. What is the extension and position of the fire?
	2.9. What is the material involved in the incident (wood, paper, chemical agents)?
	2.10. Does the building have a fire protection system?
3.	What human resources should be triggered?
4.	What materials or equipment must be used?
5.	What organs will be triggered?
6.	What is the form of communication?
7.	What actions will be taken and by what competent team?
8.	Are there victims in the incident? What is the situation of the victims?
9.	What are the elements involved and their relation with the incident?
10.	What are the risks?
11.	What are the operational phases?
12.	What are the tactical priorities?
13.	What is the work zone?

rescue, pre-hospital care and assistance to the community. This ontology is available in Portuguese and English languages (*https://recsysufba.wordpress.com/ontology/*).

3.1 Step I—Specification

In this phase, techniques, methods and activities were carried out in order to obtain necessary information for defining the scope of the project. To obtain the responses, we therefore carried out three unstructured interviews with specialists of the Military Fire Department of Bahia, Brazil. The experts involved have roles, activities and distinct responsibilities within the corporation such as operation command, emergency command and coordination of the central telecommunications system (190) of the Fire Department.

The interviews were transcribed for further data analysis and the responses helped delimiting the scope. The scope was delimited from the feasibility analysis and the necessary documents have been selected. After understanding the needs of the organizations we elaborated 23 competency questions (13 main questions and 10 subquestions). Table 1 shows some competency questions which were defined. This step was performed over a period of three months (bet-ween January and March, 2015). From the responses, we established the following scope:

- Based on the recommendation of the experts section, the domain of the ontology is fire in buildings;
- For domain conceptualization, we will use documentation, technical manuals and instructions of the Fire Brigade of Sao Paulo State as a reference of organization in the country;
- The focus of the ontology will be in the rescue tactical phase;
- The ontology will contribute to documentation and standardization of the emergencies response protocols related to fires in buildings.

Table 2 Extraction of terms and definitions.

ID	Term	Definition
6.2.1	Incident?	An occurrence or event, natural or man made, that requires an emergency response to protect life or property.

Table 3 Object property.

ID	Domain	Object Property	ID	Range
6.2.1	Incident	hasVictim	**3.5.1**	Victim

Table 4 Data type property.

ID	Data type property	ID	Domain	Range
8.1.1	isWalking	**3.5.1**	Victim	boolean

3.2 Step II—Conceptualization

After the specification phase, we started to develop of the domain conceptual model. We used the manual coding technique [17] for content analysis of the documents selected in the specification phase. Hence, we set up the conceptual mapping of domain. The terms and definitions were grouping by subject, in which the *ID* (document code + text code + summary theme code) is the reference of extraction. The documents analyzed were:

- A Collection of Fire Technical Manuals - MTB 32 - Strategic and Tactical Fire Fighting, with 154 pages - Military Fire Brigade of the State of Sao Paulo - Brazil [19];
- A Collection of Fire Technical Manuals - MTB 16 - Manual of Fire Fighting in Tall Buildings, with 88 pages - Military Fire Brigade of the State of Sao Paulo - Brazil [20];
- Guide to Emergency Management and Related Terms, Definitions, Concepts, Acronyms, Organizations, Programs, Guidance, Executive Orders and Legislation - has 1366 pages - *FEMA* - United States [21].

During this stage, we extracted 131 terms, with their meanings, and defined 60 object properties, 30 datatype properties and 20 rules. Table 2 presents examples of extracted terms such as *Emergency* and *Fire*. Table 3 depicts examples of relationships between terms through a object property and Table 4 shows examples of datatype property.

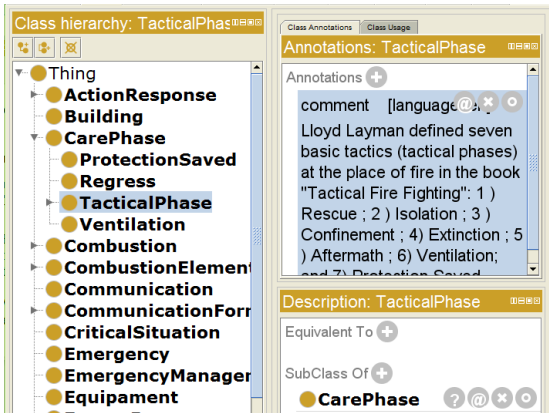


Fig. 1 103 classes created (among them, 67 are subclasses).

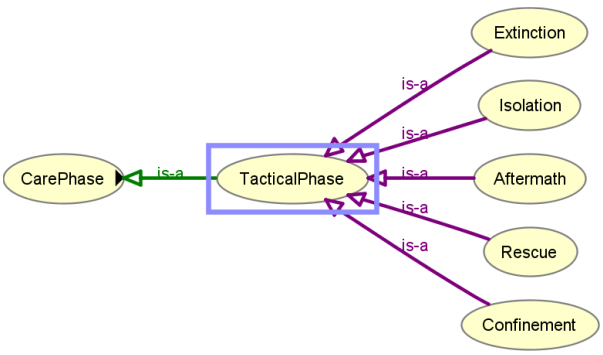


Fig. 2 Taxonomy of the class *TacticalPhase*.

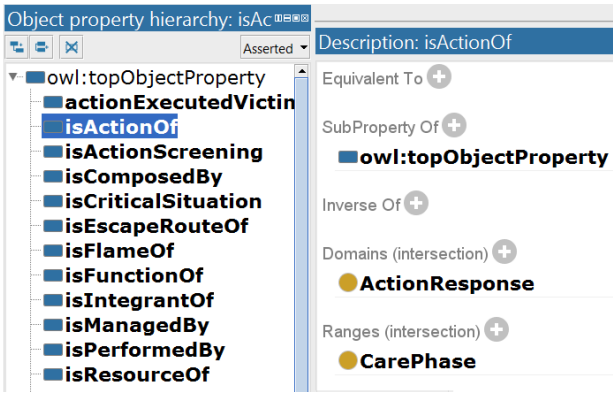


Fig. 3 The details of the object property *isActionOf* in *Protégé*.

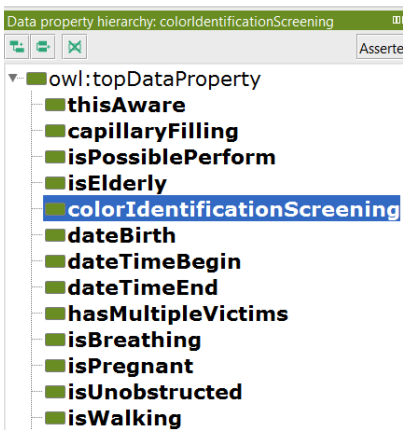


Fig. 4 Some datatype properties in *Protégé*.

3.3 Step III—Formalization and Implementation

We used the *Protégé* [22] for building the ontology. The conceptual model of the domain generated in the conceptualization step was used as a reference for creating classes, subclasses, settings, properties and rules. This stage lasted approximately 5 months (between April and August, 2015).

3.3.1 Taxonomy

The classes and subclasses were created based on information obtained in the conceptualization stage. From **131** terms extracted, most of **103** classes were created and of these **67** are subclasses. Most terms have definitions which have been described in notes. Figure 1 presents examples of classes and subclasses created.

As an example of the taxonomy created, the class *CarePhase* has subclasses *TacticalPhase*, *Regress*, *Ventilation* and *ProtectionSaved*. *TacticalPhase* has subclasses *Rescue*, *Isolation*, *Confinement*, *Extinction* and *Aftermath*. Figure 2 shows the taxonomy of the subclass *TacticalPhase*.

3.3.2 Object Property

Object properties are used to relate the individual of a class with the individual of another class [23]. From **60** object properties defined in the extraction process, **34** were created in the *Protégé* tool. A total of **26** object properties were rejected because they were out of the scope which was defined during the specification stage or were irrelevant.

The property *isActionOf*, for example, associates the individual of the class *ActionResponse* (domain) with the individual of the class *CarePhase* (range). Thus, it is defined that the care phases are composed by response actions to the incident (as shown in Fig. 3).

3.3.3 Datatype Property

Datatype properties are used to link an individual to a primitive value (string, boolean and others) [23]. We created **26** datatype properties in *Protégé*. Examples of these properties are: Boolean (*isWalking*, *isBreathing*), String (*colorIdentificationScreening*) and others (as shown in Fig. 4).

3.3.4 Instances

Instances were defined after the creation of classes, subclasses and properties. An instance is the concretion of a class, in which represents a single individual in a hierarchy [24]. For example, the class *Organization* and the subclass *MilitaryFireBrigade* have instances *MilitaryFireBrigadeBA* and *MilitaryFireBrigadeSP* respectively. Figure 5

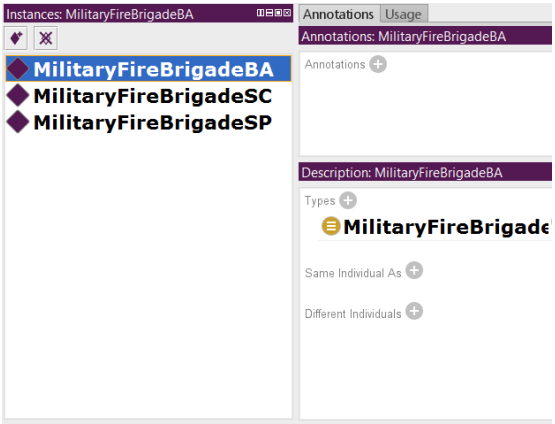


Fig. 5 Some instances of type *MilitaryFireBrigade* in *Protégé*.

presents some examples of created instances of the type *MilitaryFireBrigade*. We also created **34** instances (32 exis-ting and 02 included by experts), mostly focused on response actions for the rescue tactical phase. In the next subsections we will be presented rules and inferences made, taking as base, classes, subclasses, properties and instances previously defined and built in *Protégé*.

3.3.5 SWRL Rules and Inferences

To create rules we used the *SWRL* language and for reasoning we used Pellet [25]. One of the main advantages of *SWRL* is its ease of use, since is specified in *OWL - Web Ontology Language* [23], [26], [27]. The rules were implemented in *Protégé* and covered the rescue tactical phase, more precisely the victims screening process.

To perform the screening, many organizations in Brazil use the method S.T.A.R.T. (Single Triage and Rapid Treatment) [28]. For this reason, several rules and instances created were focused in this protocol. Others factors also motivated the use of the method for implementation the rules such as: This is a standard protocol used by most organizations in Brazil and it is well referenced in other countries like the United States [29], the process is part of the priority service which is the rescue of victims and this initial focus was an indication of the specialists.

We created **21** rules with the purpose of making inferences. For demonstration of some rules created, we will give a hypothetical example of emergency scenario. At a particular fire incident in a building some questions need to be answered such as:

Q1. Is there any victim?

Q2. Should the victims screening be carried out?

Q3. What actions will be taken?

Q4. Which resources will perform the actions?

Based on the above questions we set up the following rule: "If the particular victim is breathing and his breathing per minute is less than or equal to 30, THEN

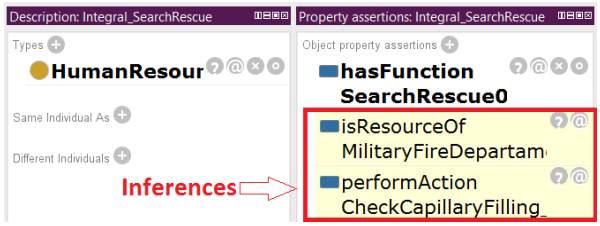


Fig. 6 Example of the inference.

SET the human resource function with *Search and Rescue* will perform the action *Check Filling Capillary*". In *SWRL* this rule is written as follows: ***Victim(?x), hasFunction(?z, SearchRescue01), breathPerMin(?x, ?y), isBreathing(?x, true), lessThanOrEqual(?y, 30)->performAction(?z, CheckCapillaryFilling-01)*** (as shown in Fig. 6).

4. Evaluation of the EmergencyFire

The ontology was evaluated based on qualitative research approach [18], [30]. This process occurred in 2 phases: i) the experts evaluated the concepts and taxonomy and ii) the experts evaluated the rules and instances for a number of emergency scenarios.

4.1 Evaluating Concepts and Taxonomy

The objective of this first stage is to assess the correctness and acceptance of the concepts and taxonomy for the construction of the classes, class expression axioms (*SubClassOf*, *EquivalentClasses*, *DisjointClasses*, *DisjointUnion*), object properties and datatype properties of the ontology.

We invite two experts of the Military Fire Brigade of Bahia (Sub commander of the Military Fire Brigade Group and Emergency Call Center Coordinator) to participate of the evaluation. The experts analyzed the classes, axioms and properties. They were fully assisted for any questions in regards during the analysis. After understanding the whole ontology model, they were asked to indicate those items to be rejected and suggest other concepts to be included in the ontology.

This phase occurred in parallel to the conceptualization stage (Sect. 3.2). During a period of 6 days, the experts analyzed **131** concepts, **60** object properties (relationships between concepts) and **30** datatype properties (characteristics of concepts). The time dedicated to the activity was in charge of the specialists, varying from 2 to 4 hours daily.

By strictly following a qualitative research methodology [18], the evaluation (approval, rejection, inclusion) of concepts extracted from the technical documents was carried out based on the experience of the specialists. For this activity, they used indicative colors. The green color was used to indicate approval, the red color was used to indicate exclusion, the yellow color was used to indicate inclusion and the purple color was used to indicate lack of knowledge. We inserted a column ID to identify the document from which the concept was extracted (manual coding [17]).

Table 5 Some examples of the result of the activity.

ID	Class (possibility)	Meaning	Subclass (possibility)
7.3.1	Work zone	Is the zoning of the incident area according to risk.	Cold zone, Warm zone and Hot zone.
1.7.4	Physical aspects of the place	General physical aspect of the area where the operations will not take place, especially with respect to the conditions that may interfere, such as electric wires and railroad tracks.	———
4.7.3	Garrison member	Components that integrate the emergency response team.	Commander, Subcommander, Lifeguard, Operator, Auxiliary and Conductor.
5.39.	Flame propagation rate	Product of the heat evolution factor by the flame propagation factor.	———

Table 5 presents examples of the assessment.

In general, some concepts were accepted (*incident*, *work zone*, *fire*, *emergency*, *fire class*, *smoke*, *victim*), others were rejected (*opening for other buildings*, *chain reaction*, *physical aspects of the location* and *area*) because they were ambiguous, redundant or not really meaningful and other term was suggested e.g. *garrison member* either to enrich the ontology.

4.1.1 The Results Obtained

The experts approved **85** concepts, which were later used in the definition of the taxonomy. The results are:

- From **131** concepts, **26** exclusions were indicated such as *material involved* and *area*;
- From **131** concepts, the experts warned **19** (*construction material of the building* and *fluids or gases of the fire*) to be unfamiliar or unknown them, so they were not used;
- The inclusion of **1** concept was indicated (*Garrison member*);
- **86** concepts have been approved such as fire, emergency and response action (**85** already existing + **1** included).

The **86** approved concepts and their descriptions were used in the definition of the taxonomy. From this analysis, **103** classes were created, of which **67** are subclasses. Regarding the properties of the object, **54** properties were approved. The results are:

- From **60** defined properties, **54** were approved such as *HumanResource - performAction - ResponseAction*;
- From **60** defined properties, lack of knowledge about **6** was indicated such as *Flame - hasPropagationIndex - FlamePropagationIndex*;
- No exclusions were indicated;
- No inclusions were indicated.

From **54** object properties approved, **34** were implemented, **20** were not implemented because they are outside the delimited scope. Furthermore, they indicated lack of knowledge about **06** properties. Regarding datatype properties, **26** properties were approved. The results are:

- From **30** defined properties, **26** were approved such as *color of the smoke*, *direction of the wind* and *status of the victim*;
- From **30** defined properties, lack of knowledge about **4** was indicated such as *structural element of the building* and *fire behavior*;
- No exclusions were indicated;
- No inclusions were indicated.

All **26** datatype properties approved were implemented. The others were not used because they were flagged with as lack of knowledge.

4.2 Evaluating Rules and Instances

The objective of this second stage was to evaluate the **21** rules and **32** instances defined. For this, an online questionnaire was applied with **13** questions to specialists after the implementation of the ontology. The experts, according to their experiences, approved some rules and indicated inclusions and exclusions of terms. This stage lasted 10 days and occurred after the phase of formalization and implementation. The questionnaire was sent by e-mail to a group of experts, but only 2 of them answered, 01 Sub Commander of the Military Fire Brigade of Bahia and 01 Major of the Military Fire Brigade of Pernambuco.

A period of 6 days was provided to complete the initial activity (questionnaire response). The time dedicated to the execution was based on their availability. Only two of them answered the questionnaire however this did not impact negatively due to the experience time of both (approximately 25 years).

4.2.1 The Results Obtained

We evaluated **20** rules and **32** instances defined through the documents (technical standards, manuals and guides) analyzed. With the analysis of the answers of the questionnaires, results as approvals, inclusions and exclusions were obtained. The results are:

- **32** instances were approved such as *AutoPumpTank* and *AutoPumpRescue* that belong to subclasses of the *Vehicle* class;
- Inclusion of **2** instances such as *MotoRescue* and *RescueUnit*;
- No instance deletion was indicated;
- No lack of knowledge was indicated.

All instances were added to the ontology. With respect to the rules, as already demonstrated, the focus remained on

the victims screening process. Some of the results are:

- Approval of **20** rules such as *if the victim is breathing, and breath per minute is greater than 30, then victim receives the red identification color* and *if the victim has red identification color, it receives the urgent status*;
- Inclusion of rule, for example, *the victim screening process only runs in incidents with multiple victims*;
- No rule deletion was indicated;
- No lack of knowledge was indicated.

4.3 Discussion

We were very careful in the ontology evaluation process. The use of methods and techniques based on the qualitative research approach greatly enriched the content of our work. The fact that the author of this article to work with the specialists facilitated the contact and helped in the execution of the activities. The methods applied (unstructured interviews, documentary analysis and others) were not automated. This gave qualitative value to the results and decreased the possibilities of errors.

During the research we faced with some limitations such as: i) the size of the sample of specialists involved was small and its population limited (the impact of this limitation was minimized by the qualification and time of experience of the specialists), ii) dependence of the specialists to carry out the research and iii) the absence of a case study or experiment to evaluate the practical usability of the ontology (we can point out it was not the focus of this research).

5. Applicability of the EmergencyFire

In this section we present an example of applicability of the *EmergencyFire*. The goal is to implement the tool as future work since at this moment the focus is the construction of the ontology. The application will support the strategic, tactical and operational planning of the involved organizations, being able to be used in training and simulations as well as in real situations. The fact that the author of this paper works at the Public Security Department added values throughout the research.

The intended system will provide mechanisms for organizations to approach incidents based on protocols specified in the ontological model approved by domain specialists. The user will input information related to the emergency scenario and the application will respond with the protocol to be performed (actions to be executed, resources and organizations involved, among others). An example of the initial prototype is shown in Fig. 7.

The prototype was presented to two specialists of the Military Fire Brigade of Bahia, who participated in the ontology specification and evaluation phase. We obtained as a result a favorable critical analysis approving the main idea of the tool but also outlining suggestions on how to improve the layout and to add new functionalities. One interesting suggestion was to create a specific module for querying the knowledge base. At that time, the intention was to approve the idea of the application through a prototype of screens, so more details were not raised. In due time, requirements will be specified, template will be drawn up and the application will be developed.

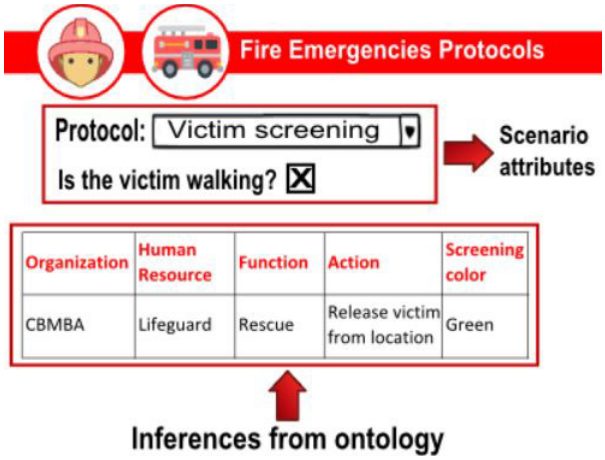


Fig. 7 An example of the applicability of the *EmergencyFire*.

6. Conclusion

This work presents an ontology whose main objective is to attenuate problems such as the lack of standardization and documentation of emergency response protocols of fire in buildings. We believe that *EmergencyFire* ontology may help organizations to quickly respond to an emergency situations of fire in buildings, since people and systems will have a common understanding of protocols.

The development of the ontology was based on interviews, conceptual analysis of documents (manuals, guides, norms and technical terms) using the manual coding method proposed by Saldaña [17] and evaluated by expert. The results were satisfactory. The approved ontology comprises 103 classes, 67 subclasses, 34 object properties, 26 datatype properties, 34 instances and 21 swrl rules.

As a future work we plan to include: ontology evaluation by specialists related to agencies of other brazilian states, conducting a study to include other variables not yet evaluated, such as the insertion of new emergency response protocols, implementation of application that consumes the created ontology (axioms and concepts), and execution of case study to attest the applicability of the *EmergencyFire*. In this way, new contributions will be added to the work.

References

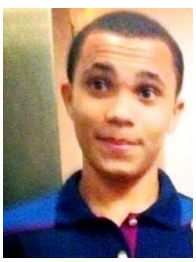
[1] FEMA, "Federal Emergency Management," http://www.fema.gov/, accessed July 19. 2014.
[2] EXAME, "The biggest fires in brazil," http://exame.abril.com.br/bra-sil/os-maiores-incendios-no-brasil/, accessed July 3. 2015.
[3] Globo.com, "Errors that contributed to kiss tragedy," http://exame.-abril.com.br/brasil/noticias/os-maiores-incendios-no-brasil, acces-sed July 3. 2015.

[4] T. Berners-Lee, J. Hendler, and O. Lassila, "The Semantic Web," Scientific American, vol.284, no.5, pp.34–43, May 2001.
[5] T.R. Gruber, "A translation approach to portable ontology specifications," Knowl. Acquis., vol.5, no.2, pp.199–220, June 1993.
[6] R. Fikes, "Multi-use ontologies," http://www.ksl.stanford.edu/people-/fikes/cs222/2001/ontologies/tsld001.htm, accessed Feb. 10. 2014.
[7] D. PROJECT, "DiRes Ontology - Emergency and Disaster Response Semantic Interoperability," http://www.disaster20.eu/dires, accessed July 7. 2014.
[8] D. PROJECT, "EMERGEL | EMERGency ELements. 2007 - 2013," http://vocab.ctic.es/emergel/, accessed July 7. 2014.
[9] P.S.L.A.R.B.M.G.L. Barros, R.; Kislansky, "EDXL-RESCUER ontology," Proceedings of the ISCRAM 2015 Conference - Kristiansand, pp.24–27, May 2015.
[10] M.I. Bosca, K. Cordeiro, J. Oliveira, and M.L.M. Campos, "Ontoemerge: Construção de uma ontologia core para a área de emergências baseada em ontologia de fundamentação," 3o Ontobras-Seminário de Pesquisa em Ontologia no Brasil, Florianópolis, 2010.
[11] K. Kalabokidis, N. Athanasis, and M. Vaitis, "OntoFire: an ontology-based geo-portal for wildfires," Nat. Hazards Earth Syst. Sci., vol.11, no.12, pp.3157–3170, 2011.
[12] Connection Tocantins, "SOS 193," http://conexaoto.com.br/2015/11/-06/em-menos-de-dois-meses-aplicativo-sos-193-ja-contabiliza-mais-de-dois-mil-downloads, accessed Sept. 15. 2015.
[13] ABIMDE, "The goal of the national industry," http://www.defesanet.-com.br/bid/noticia/15639/O-Gol-da-Industria-Nacional, accessed May 3. 2015.
[14] K. Bitencourt, F. Durão, and M. Mendonça, "Emergencyfire: An ontology for fire emergency situations," Proc. 21st Brazilian Symposium on Multimedia and the Web - WebMedia '15, pp.73–76, 2015.
[15] M.F. Lopez, A. Gomez-Perez, J.P. Sierra, and A.P. Sierra, "Building a chemical ontology using methontology and the ontology design environment," IEEE Intelligent Systems, vol.14, no.1, pp.37–46, Jan. 1999.
[16] N.F. Noy and M.A. Musen, "Prompt: Algorithm and tool for automated ontology merging and alignment," Proceedings of the Seventeenth National Conference on Artificial Intelligence and Twelfth Conference on Innovative Applications of Artificial Intelligence, pp.450–455, 2000.
[17] J. Saldana, The Coding Manual for Qualitative Researchers, SAGE Publications, 2012.
[18] E.D. Nunes, "The challenge of knowledge: qualitative research in health," Ciência & Saúde Coletiva, vol.12, no.4, pp.1087–1088, 2007.
[19] CBMSP, "MTB 32 - Strategy and Tactics of Fire Fighting," http://pt.slideshare.net/roaugustus2010/mtb-32-estratgia-e-tatica-de-combate-a-incndio?related=3, accessed March 08. 2015.
[20] CBMSP, "MTB 16 - Manual of Fire Fighting in Tall Buildings," http://pt.slideshare.net/dougkkk/mtb-16-combate-a-incndios-em-edifcios-altos?related=2, accessed March 8. 2015.
[21] B.W. Blanchard, "Guide to Emergency Management and Related Terms, Definitions, Concepts, Acronyms, Organizations, Programs, Guidance, Executive Orders & Legislation," http://training.fema.gov/hiedu/docs/terms and definitions/terms and definitions.pdf, accessed March 8. 2015.
[22] Stanford University, "Protégé - Stanford," http://protege.stanford.edu/, accessed March 5. 2015.
[23] W3C, "Owl web ontology language overview," http://www.w3.org/-TR/owl-features/, accessed July 19. 2014.
[24] A. Maedche, Ontology Learning for the Semantic Web, Springer Science & Business Media, 2012.
[25] W3C, "SWRL: A Semantic Web Rule Language Combining OWL and RuleML," http://www.w3.org/Submission/SWRL/, accessed Nov. 10. 2014.
[26] W3C, "Pellet - semantic web standards," https://www.w3.org/2001/-sw/wiki/Pellet, accessed July 3. 2015.
[27] I. Horrocks, P.F. Patel-Schneider, H. Boley, S. Tabet, B. Grosof, M. Dean, et al., "Swrl: A semantic web rule language combining owl and ruleml," W3C Member submission, vol.21, p.79, 2004.
[28] COREN - SP, "The acting of the nursing team in accidents with multiple victims," http://inter.coren-sp.gov.br/, accessed Dec. 20. 2014.
[29] M. County, "The S.T.A.R.T. method," http://www.mariposacounty.-org/DocumentCenter/Home/View/3336, accessed Dec. 18. 2014.
[30] S. Lovrencic and M. Cubrilo, "Ontology evaluation-comprising verification and validation," CECIIS-2008, 2008.

Kattiuscia Bitencourt is a Bachelor in Systems Analysis from State University of Bahia (2004), Master in Computer Science from Federal University of Bahia (2016). My activities are focused in the areas of Software Engineering and Data Mining, acting on the following topics: Requirements analysis, software testing, systems documentation, analysis and adaptation of content and data management.

Frederico Araújo Durão obtained his PhD in Computer Science from the University of Aalborg, Denmark, in 2012. Before, Fre-derico earned his BS in Computer Science in the Faculty Ruy Barbosa in 2004 and his Masters in Computer Science at the Federal University of Pernambuco in 2008. Nowadays is employed as teacher and researcher by the Federal University of Bahia.

Manoel Mendonça holds a BS in Electrical Engineering from the Federal University of Bahia (1986), Master's Degree in Computer Engineering and Industrial Automation from the State University of Campinas (1990) and a PhD in Computer Science from the University of Maryland at College Park (1997). Currently is Professor of Computer Science at the Federal University of Bahia.



Lassion Laique Bomfim de Souza Santana is a Bachelor student of Computer Science - Federal University of Bahia, currently a scholar and researcher in Wiser (Web and Interactive Systems Research Group) Recommendation Systems area, oriented by Prof. Dr. Frederico Araújo Durão. He worked as a system developer. He developed applications using SQL Server and .NET. His areas of interest include: Recommender Systems and Mobile Devices.