Semantic Representations of Actors and Resource Allocation through Reasoning in Humanitarian Crises

Aladdin Shamoug
University of Westminster
a.shamoug@my.westminster.ac.uk

Radmila Juric
University of Westminster
r.juric@wmin.ac.uk

Shamimabi Paurobally
University of Westminster
s.paurobally@wmin.ac.uk

Abstract

Humanitarian reporting is the backbone of responses to humanitarian crises, which is based on various types of decision making, mostly taken at the highest level by those who fund the humanitarian response. The lack of accurate information is a well-known problem, which increases the risk of failure and may affect humanitarian response. In this paper we illustrate how each situation in crises can be described through the semantic representations of actors potentially involved in it, for the purpose of deciding on their correct engagement in humanitarian responses. Consequently, we underpin the automatic resource allocation for humanitarian response with computations based on OWL/SWRL enabled ontologies and reasoning. The prototype has been implemented as a software application created with Java technologies, which utilizes OWL-API and runs the proposed reasoning process.

1. Introduction

Decision making in humanitarian crises (HC) is a complex procedure which should create efficient and timely humanitarian response (HR). HR should be tailored to a particular HC and take into account cultural, political, organizational practices and regulations. Having efficient information systems (IS), with rich and well-structured repositories, which allow the exchange of their contents, has been one of the prerequisites for informed decision making in HC. Local information in HC is also important. It can be found in various sources and formats: from satellite images and spatial data to statistical records, government intelligence and verbal/written reports of local populations. Constant changes in HC, which may happen on an hourly basis, are additional factors considered by decision makers who manage HR. They rely on such changes rather than waiting for accurate and exact information, which may come late, or not at all [1]. Decision making in HC becomes progressive and iterative, interpreting what is going on rather than what should be done [2]. It should collect data from people/machines and provide a bottom-up data planning /tasking and data analysis [3] [4] [5] [6] [7].

In this paper we are interested in decision making carried out by coordinators of HR. We adopt the idea of co-ordinated needs assessment in decision making [8] [9] [10] and the use of evidence in HR in general [11] [12]. We would like to focus on resource allocation in HR, which guarantees the most effective HR and find a mechanism for the most efficient allocation of financial support, human skills and experience, technology and knowledge, food, water, health services, nutrition, protection and many more.

Our motivation is threefold. Firstly, attention has been drawn to resource allocation in HR since 2005 [13]. The relationship between humanitarian needs assessment, which indicates resource allocations, and decision-making in HC was mentioned 10 years ago [14] and has redefined the humanitarian aid agenda [15]. However, there is no published work which implements automatic resource allocation for HR.

Secondly, we intend to promote a shift in thinking on which types of information are needed for allocating resources in HR. They might not come solely from ISs or documentations we have on HC.

Thirdly, decision making at the HR coordinator's level should be an iterative process. Constant changes in circumstances during HR must be addressed as they happen. We intend to support resource allocation on a daily basis through reasoning upon a particular *situation* encountered in HC. It can be done through reasoning using Ontology Web Language (OWL)/Semantic Web Reasoning Rules (SWRL) enabled computations, resulting in automated resource allocation. Semantic Web Technologies [16,17,18] used for automating resource allocation enables automated reasoning when managing HR. We can address the semantic of *situations* in HC through OWL ontologies and extend them towards collaboration and situation awareness as debated in [19, 20].

In section 2 we describe the problem domain, in section 3 we give a scenario of a situation in HC and in section 4 we describe the proposed software engineering solution for decision making at the

978-1-4799-2504-9/14 $31.00 © 2014 IEEE
DOI 10.1109/HICSS.2014.515

coordinating level in HC, which perform the resource allocation for HR through reasoning upon OWL ontologies. Section 5 covers related works and we conclude in section 6.

2. The Problem

The problem we address falls into four categories. Firstly, we look at the first few days of the HC where confusion, sporadic evidence and the lack of accurate information of the HC dominate. At that early stage all actors in the HC, e.g. donors and agencies, are getting involved, according to their own perception of and interest in the HC. However the coordinating body is the one which makes decisions on how to allocate resources for HR. If we address the decision making in the early stages of the HC, we have to *get into the mind* of the coordinating body and find out which decisions have to be made and which data are needed.

Secondly, we would like to see the decision making as a fragmented process where the coordinating body allocates resources on an ad-hoc basis. We need mechanisms of automated decision making *as-we-go,* and to address changes in HC.

Thirdly, the problem of availability, accuracy, correctness, and accessibility of information might not significantly affect decision making in the early days of HC. It is more likely that actors interested in the HC and the coordinating body would rely on information which is not stored in their existing ISs. In early days we rely on evidence which says: which actors might be interested in a particular HR, which donors are ready to fund it, for which sector/location we might have assistance and similar. This type of information might not be stored in any database. It can be given to the coordinating body during the first days of HC or acquired by the body, because of its role in the creation of HR. It may also be available in the coordinating body's IS built throughout years.

Finally the problem of decision making in HC is extremely complex, but we should not try to find a silver bullet for prescribing it. We are aware that resource allocation for HR is dependent on such decision making and therefore software technologies, which have power of storing and interpreting the semantic of and understanding the needs in HC, are the way forward. If we adopted the idea of coordinated needs assessment in decision making in HC, then without interpretation of situations in HC we could not create any automated support for resource allocation.

3. The Scenario

In South West Somalia (L1), we have suddenly discovered drought, through media reports, which stated that there are cattle dying and people migrating toward Kenya. Some humanitarian agencies (A1, ... , Ag) have become aware of the problem and analyzed the emergency of the situation in Somalia. At the same time various donors (D1, ..., Dj), have also become aware of the crises in Somalia and are assessing the possibilities of getting involved. The media information is not sufficient for organizing any HR. Agencies may try to approach other sources of information in SW Somalia; donors may make their own investigations on the nature of HC, but would probably prefer to wait for agencies to appeal for assistance. A coordination body, responsible for organizing HR, is in the same situation: they have to start their own investigations before they make decisions for creating HR. They can liaise with the government of Somalia, its bodies, UN agencies, and local NGOs, that have a constant presence in Somalia. The information needed is not necessarily historical. It may be the result of the HC itself. The fact that there is a migration of people, from South West Somalia (L1) to Kenya (L2), will change the demography within these locations. This could be known to Somali government, local authorities, UN agencies in Somalia, and NGOs, but should be made available to the coordination body.

3.1. Day One: Identifying Location(s) and Possible Actors and Donors

On day one, the coordination body acknowledges that there is a HC in South West Somalia (L1). UNICEF (A1) has been known as an agency that has had a historical presence in Somalia, and could still be interested in intervention in it (L1). The coordination body also knows that UNICEF (A1) might be a good choice for intervening in (L1) because they have had experience with drought driven HC (i.e. they worked in the water sector in the past). It is very likely that USAID (D1), as a donor would be interested in funding agencies which would intervene in (L1) because of their interest in Somalia.

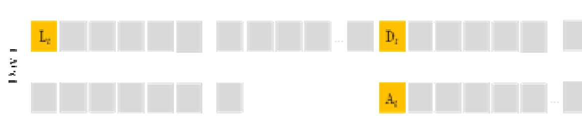

Figure 1. Day I.

In day one USIAD (D1), and UNICEF (A1) are isolated entities. The questions which need answers before the coordinating body makes decisions for resource allocation: Which agency is capable of intervening, and who would fund intervention in (L1)? Knowing the interests of USIAD (D1) and UNICEF

(A1), is USAID (D1) a suitable donor for funding UNICEF (A1), and if so, will they be allowed to be a part of HR in (L1)? Which agency should be funded by USAID (D1)? Would they fund UNICEF? Would USAID (D1) allow the use of their money in this particular HC in (L1)?

3.2. Day Two: Connecting Agencies and Donors

On day two, the coordination body would be able to oversee the scale of the HC, by clustering it into small sectors (S1,…S6) that have been generated from gathering more information in (L1). They know that in the case of drought, people migrate to other locations to protect their livelihood, but some decide to stay in (L1) and cope with the situation. Those who decide to stay might need Water (S1) and Health (S2) services. Those who migrate to new locations might need new houses/shelters (S3), new means of livelihood (S4), food (S5) for their families, and sanitation (S6) services to keep them healthy. The coordinating body must know which agency has the ability and willingness to provide the assistance and which donor has the ability and willingness to provide funds (to those agencies).

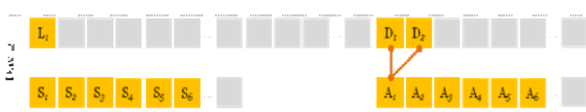

Figure 2. Day II.

On day two, the coordination body recommends that USAID (D1) and DFID (D2) donate funds to UNICEF (A1), shown by orange lines in the right part of Figure 2. By end of day two, UNICEF (A1) might not be the only agency interested in intervention in the current HC. WHO (A2), UNHCR (A3), Oxfam (A4), RI (A5), and NCA (A6), with donor profiles: USAID (D1) and DFID (D2), are all interested, but the coordination body would know that none of them will be funded by the available donors (D1-D2). The ability of the coordination body to fully allocate resources is still limited. They do not know which of the six known sectors (S1-S6) is going to be filled in (L1). It would be beneficial if HR were categorized into manageable sectors, to be assigned to different locations in future. Instead of having all agencies (A1, ..., Ag) working together in all sectors (S1, ..., Sk), and choosing randomly what they want to do, the coordination body should allocate each sector a single agency to be in charge of. However, it might not allocate "sector leaders" before knowing the exact location for each sector!

3.3. Day Three: Defining Boundaries of Sectors and Locations

On day three it has become clear that (L1) needs only: Water (S1) and Health (S2), while Kenya (L2) needs Shelter (S3). Therefore we have three blue lines in Figure 3. This decision is based on (i) coordination body experience: they have been (L1) since 1990 and (ii) information collected in (L1).

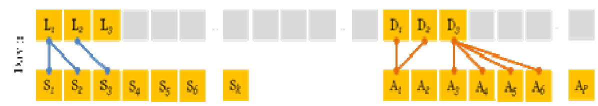

Figure 3. Day III.

The humanitarian presence which has existed in (L1) is a set of agencies (Ai, i=1,..g), which show strong interest in helping Somalia from the first day of HC. They might have been present in (L1). but in a different internal location or sector. On day three they are able together with their implementing partners confirm connections between L1 and S1 and S2 and between L2 and S3. We may have more locations in this HC: L3, ... Lq could be some inner locations within Somalia or adjacent countries like Ethiopia (L3). We may also have sectors, such as livelihood (S4), food (S5), sanitation (S6), appearing at any moment, but they have not been associated with any location yet. At the same time the coordination body is able to make more decisions and connect donors with agencies and have better allocation of resources. They learned that Oxfam (A4), Relief International (A5) and Norwegian Church Aid (A6) are interested in the HC, and that the donor D3, Canadian International Development agency (CIDA), is willing to donate to UNHCR (A3), Oxfam (A4), Relief International (A5) and Norwegian Church Aid (A6). However, some agencies, such as WHO (A2), may not need any donor because they have reserved funds for the HC.

3.4. Day Four: Disappearance of Donors

In day four (L1) is ready to receive assistance such as: water (S1) and medical assistance (S2), from those who are willing to provide both: UNICEF (A1), and WHO (A2). Kenya (L2) is ready to receive shelter (S3), from UNHCR (A3) and Oxfam (A4), for the newly arrived migrants. Each combination of Li/Sj should be allocated to one or more Ak.

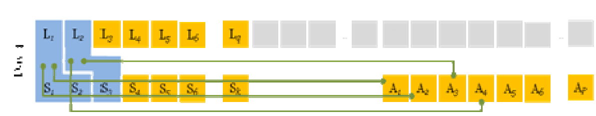

Figure 4. Day IV.

The coordination body gives the following allocation (green lines in Figure 4). Firstly, UNICEF (A1) is the most experienced agency in water supply (S1), WHO (A2) is the most experienced in providing health services (S2) and the UNHCR (A3) and Oxfam (A4) have experience in accommodating refugees and providing shelter for them (S3). Secondly, (L1) needs: water (S1) and health (S2); and Kenya (L2) needs only shelter (S3) services to accommodate Somali refugees. These imply that UNICEF (A1) must be deployed in (L1) to provide water (S1); WHO (A2) must be deployed in (L1) to provide health services (S2) and UNHCR (A3) and Oxfam (A4) must be deployed in Kenya (L2) to provide shelter (S3). The coordinating body may also learn that since yesterday RI (A5) and NCA (A6) are funded but not deployed for various reasons. RI (A5) and NCA (A6) have a presence in other locations, such as Ethiopia (L3), Djibouti (L4), which have no allocated sectors. RI (A5) and NCA (A6) might have experience in other sectors, such as: livelihood (S4), food (S5), sanitation (S6), ... (Sk), which have not yet been associated with any location.

3.5. Day Five: Implementing Partners Take the Lead

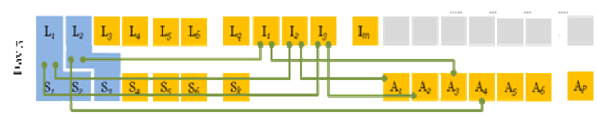

Figure 5. Day V.

On day five agencies such as: UNICEF (A1), WHO (A2), and UNHCR (A3) may decide to outsource some of their mandates to implementing partners such as: Somali Red Crescent (I1), Ministry of Health (I2), and local NGO (I3), to provide the same services for the (L1) and (L2) and sectors: water (S1), medical help (S2), and shelter (S3). The purpose is to increase the efficiency in HR, because implementing partners are, usually, able to provide the same services in less time and cost, and with a better outcome. They may have local experience from previous assignments and technical knowledge of designated sectors. Hiring an implementing partner is optional: agencies, such as Oxfam (A4), may decide to implement its programs by itself.

4. The Proposal

We propose to support coordinating body decision making in resource allocation for HR through computations based on SWRL enabled OWL ontologies. The justification for using them is twofold. Firstly, in our previous work [21-24] we have used such computations for a variety of automated reasoning in decision making during HC. Secondly, by creating computations with SWRL, which reasons upon OWL constructs we do not create a complex and formal OWL ontology. We have a relatively small and efficient set of OWL constructs which respond to constant changes of circumstances in HC and therefore answer our need to have ad-hoc resource allocation.

The proposed computations have two parts: they specify the way the semantic of the environment, where resource allocation takes place, is defined in an OWL ontology and the way reasoning with SWRL can support resource allocation. The ultimate goal is to house our OWL/SWRL enabled computations within software applications which run in a variety of environments underpinned with communication and software technologies. Their implementation may be desk-top/web-based applications within Java Enterprise development environments or Apps for mobile hand-held devices.

The presence of OWL/SWRL enabled computations dictates which artefacts must be proposed. The description of OWL/SWRL enabled computations must comply with the vocabulary, syntax and purpose of OWL and SWRL. In order to perform reasoning with SWRL upon OWL concepts we need to create a set of competency questions which will be answered through the reasoning [18]. These competency questions often *set the scene* and help in creating ontological structures. They are closely related to questions the coordinating body may ask when making decisions for resource allocation. In our proposal, the reasoning is always based on ontological matching and therefore the ontological model should have concepts which can be *matched* and enhanced with constraints, i.e. adding more semantics and securing reasoning.

In the next subsections we illustrate our proposal by defining competency questions (CQ), the ontological structure and constraints and SWRL rules which answer the CQ. They are based on the semantics from the Scenario. The resource allocation should follow answers to these CQ.

4.1. CQ According to Days 1-5 in HC

Table 1 shows the competency questions (CQ) from the Scenario, for each day in HC and connects them with SWRL rules which we will answer them.

4.2. The OWL Ontology as Semantic Representations of Actors/Locations/Sectors

The ontological classes are derived from the Scenario and semantics of the information relevant in each day of the HC. Figures 1-5 require that the ontological classes store the semantics of all actors involved in the HC: donors, agencies and implementing partners, and include locations and sectors affected by the HC. If we wished to answer competency questions we would need class RESULTS which stores the results of reasoning.

Table 1: Competency questions

No.	Day	Question	Rule
1	I	Who are the possible agencies to intervene in those locations?	Rule-1
2	I	Who are the possible donors for those possible agencies?	Rule-1
3	I	What are the possible locations for the crisis?	Rule-2
4	II	Which sectors has been affected by the crisis?	Rule-2
5	II	Which donor is willing to fund possible crisis locations?	Rule-3
6	III	Which locations have granted funds from donors?	Rule-3
7	III	Who among agencies is able to provide certain sector?	Rule-4
8	IV	Which sectors have possible agencies to intervene in?	Rule-4
9	V	Which implementing partners is able to provide help for confirmed sectors, and confirmed locations?	Rule-5
10	V	Which implementing partners is able to provide help on behalf of confirmed agencies?	Rule-6

When making decisions in day I-V, we may categorize donors/agencies/implementing partners as (i) *possible*, because they have either shown their interest for or are suitable as actors in HR and (ii) *confirmed* because they are chosen and agreed to be involved in HR. The same logic applies to locations and sectors: certain locations have been affected and sectors might have been identified, but they should also be confirmed.

The relatively simple ontological structure in Figure 6 secures two important outcomes. Firstly, it allows us to have all possible actors/locations/sectors as ontological individuals and leave their descriptions and relationships to become constraints (properties). They can be dynamically defined and inferred as the situation in HC changes from day to day. Therefore the model from Figure 6 is universal, reusable for various situations in HC and relatively simple from the software engineering point of view. It will produce a stable and flexible software application which will address changes in HC through OWL constraints and not through the complexity of OWL taxonomical structure. As situations change in HC, we are able to infer constraints automatically, according to each situation. The semantics of situations in the HC will not solely be in the ontological structure and its hierarchy, but in its constraints. If the final result is a reusable ontological model, than our modeling principle outlined in Figure 6 gives a sound software engineering solution.

Secondly, it allows the modeling of the dynamics resource allocation and its volatility. The volatility of the situation in HC means that everything is possible. Sectors affected by HC might appear suddenly, and might not be allocated to a specific location. We might know that there is a need for water, health and shelter, but which one of them is needed in which location might not be clear. More and more agencies will appear on a daily basis, showing interest in current locations and sectors, but they need to have committed donors to support their interest. However strong their desire to get involved in HR is, some agencies will never get an initial commitment from some donors. Some donors may change their mind and fund agencies even if their policies and regulations do not encourage them to do so. These complex and volatile relationships between actors/locations/sectors should NOT be interwoven in the basic ontological model. They should be inferred through constraints as situations in HC change.

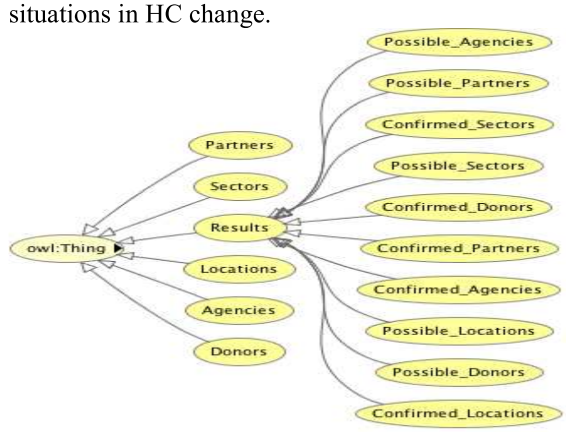

Figure 6. The Ontological Classes

4.3. OWL constraints: object properties which connect Actors/Locations/Sectors

Table 2 gives us a snapshot of constraints from the Scenario, which may be defined upon OWL classes. They are OWL object properties defined on individuals from the range and domain classes. There are no limits on the number of them and we may have a set of different object properties defined upon individuals of the same domain and range classes. Not all individuals from a particular domain class should be related through object properties to individuals of another class. The choices of individuals which participate in relationships may be defined manually (assertion) and automatically (inference), depending on a situation in HC. Object properties given in Table 2 are important for ontological matching. Without the correct assertion or inference of properties we cannot perform it.

A full scale implementation of the ontological model might require a richer set of properties. They could be defined on an ad-hoc basis and according the specificity of the HC.

Table 2: Object Properties

	Domain Class	Object Property	Range Class
1	Donor	is_willing_to_fund	Agency
2	Locations	is_in_need_for	Sectors
3	Possible Donors	has_an_interest_in	Possible Locations
4	Possible Agencies	has_to_provide	Possible Sectors
5	Partners	has_operations_in	Confirmed Locations
6	Partners	has_experience_in	Confirmed Sectors
7	Possible Partners	is_hired_by	Confirmed Agencies

Object properties from Table 2 are basic constraints for reasoning rules upon constantly changing individuals of actors/ location/ sectors.

4.4. Ontological Reasoning: Answers to CQ

We illustrate ontological reasoning through 6 SWRL rules which give answers to the CQ listed in Table 1. The selection of rules is not the only viable set of reasoning steps which may answer the CQ. Our rules are influenced by the selection of object properties from Table 2 and therefore their semantics are tightly connected to the way we express relationships in the Ontology. Different inference of object properties might results in different types of SWRL rules. Most rules can be written in advance, and some could be generated on an ad-hoc basis. This is particularly feasible when the syntax of rules does not include literal values and hard-coding. In the next 6 subsections we illustrate each SWRL rule with (a) its syntax, (b) a set of ontological classes involved in the reasoning and classes which store its results and (c) screen shots of individuals of RESULT subclasses which have answers to the CQ. We may perform reasoning upon classes which store inferred individuals from previous reasoning, which are subclasses of the RESULT classes.

4.4.1. Rule-1: Reasoning upon Donors and Agencies. This rule responds to the 1st and 2nd CQ in Table 1, and matches two classes: Donors and Agencies. It infers individuals from both classes, which participate in the property "willing_to_fund". The box shows the rule: the individuals from Donors/Agencies which participate in the property are moved into (Possible_Donors) and (Possible_Agencies) classes. Figure 8 is a screenshot of inferred individuals, i.e. copies of individuals from Donors and Agency which participate in the property from the rule.

Donors(?D) ∧ Agencies(?A) ∧ is_willing_to_fund(?D, ?A) → Possible_Donors(?D) ∧ Possible_Agencies(?A)

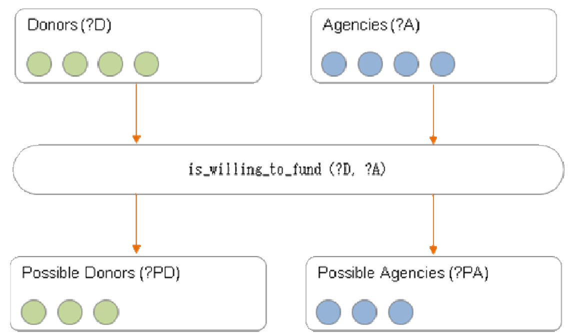

Figure 7. Rule1: Reasoning upon Donors and Agencies

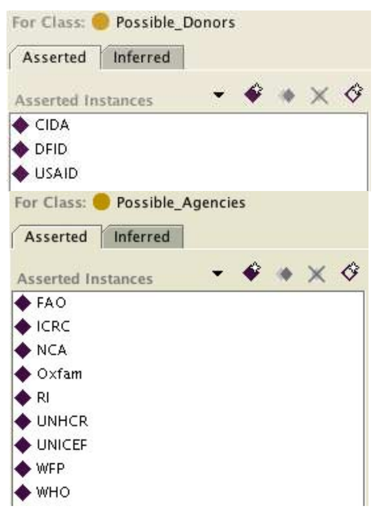

Figure 8. Results of Rule1: List of Possible Agencies and Donors

4.4.2. Rule-2: Reasoning upon Locations and Sectors. This rule responds to the 3rd and 4th CQ and matches Sector and Location classes. It infers the individuals from both classes, which participate in the property "is_in_need_for". The box shows the rule: the individuals from Sectors and Locations which participate in the property are moved into Possible_Sector) and (Possible_Locations) classes respectively. Figure 10 is a screenshot which shows inferred individuals.

Locations(?L) ∧ Sectors(?S) ∧ is_in_need_for(?L, ?S) → Possible_Locations(?L) ∧ Possible_Sectors(?S)

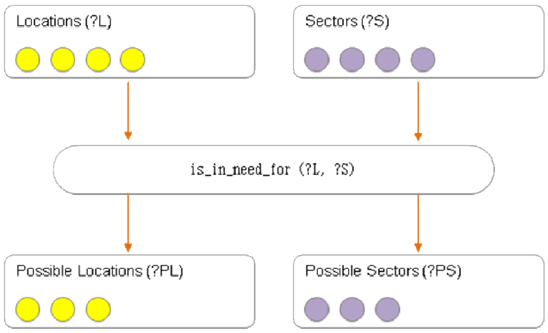

Figure 9. Rule2: Finding Possible Locations and Sectors

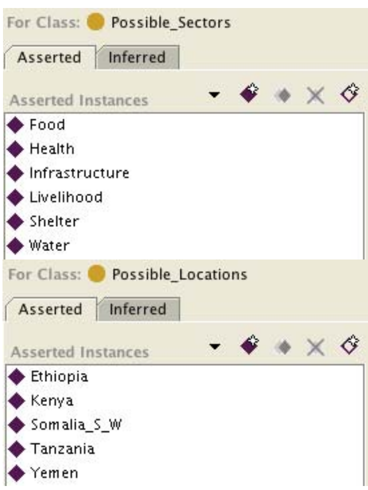

Figure 10. Result of Rule2: List of Possible Locations and Sectors

4.4.3. Rule-3: Inference of Confirmed Donors and Locations. This rule responds to the 5th and 6th CQ questions from Table 1, and matches two classes which are subclasses of the RESULT class: (Possible_Donors) with (Possible_Locations). It infers the individuals, from both classes, which participate in the property "has_an_interest_in". The box shows the rule: the individuals from Possible_Donors and Possible_Locations which participate in the property are moved into (Confirmed_Donors) and (Confirmed_Locations) classes respectively. Figure 12 is a screenshot which shows inferred individuals.

Possible_Donors(?PD) ∧ Possible_Locations(?PL) ∧ has_an_interest_in(?PD, ?PL) → Confirmed_Donors(?PD) ∧ Confirmed_Locations(?PL)

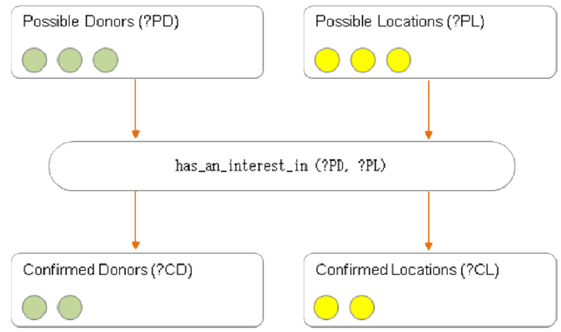

Figure 11. Rule3: Confirming Donors and Locations

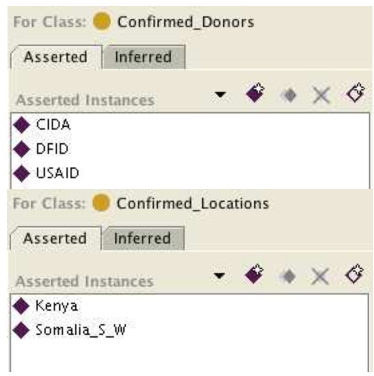

Figure 12. Result of Rule3: List of Confirmed Donors and Sectors

4.4.4. Rule-4: Inference of Confirmed Agencies and Sectors. This rule responds to the 7th and 8th CQ. It matches two classes which are subclasses of the RESULT class: (Possible_Agencies) with (Possible_Sectors) and infers the individuals, from both classes, which participate in the property "has_to_providee". The box shows the rule: the individuals from Possible_Agency and Possible_Sectors which participate in the property are moved into (Confirmed_Agency) and (Confirmed_Sector) classes respectively. Figure 14 is a screenshot which shows inferred individuals.

4.4.5. Rule-5: Inference of Possible Implementing Partners. This rule responds to the 9th CQ. It matches two subclasses the RESULT class: (Confirmed_Sector) and (Confirmed_ Locations) and class PARTNERS from the base ontological structure. It infers the individuals, from the PARTNER class. They participate in two properties: "has_an_operation_in" and "has_ experience_in". The box shows the: the individuals from the PARTNER class, which participate in both properties, are moved into (Possible_Partner) classes. Both properties are important: each inferred partner must have current presence in Possible_Locations, and has to have previous experience in Possible_Sectors. Figure 16 is a screenshot with possible implementing partners.

4.4.6. Rule-6: Inference of Confirmed Partners. This rule responds to the 10th CQ. It matches two subclasses of the RESULT class: (Possible_partners) and (Confirmed_Agencies) and infers the individuals, from the (Posible_Partners) class, which participate in the property "is-hired_by". The box shows the rule: the individuals from Possible_Partners and Confirmed_Agencies which participate in the property are moved into (Confirmed_Partners) class. Fig. 18 is a screenshot which shows inferred individuals.

Possible_Agencies(?PA) ∧ Possible_Sectors(?PS) ∧ has_to_provide(?PA, ?PS) → Confirmed_Agencies(?PA) ∧ Confirmed_Sectors(?PS)

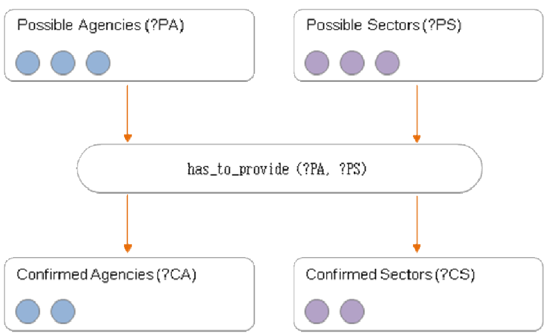

Figure 13. Rule4: Confirming Agencies and Sectors

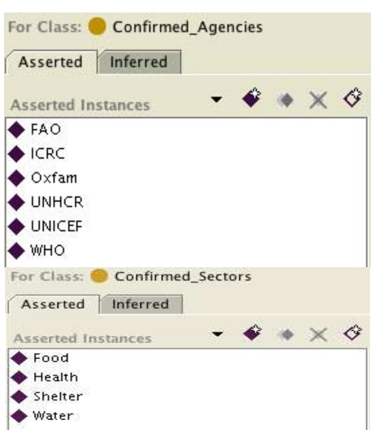

Figure 14. Results of Rule4: List of Confirmed Agencies and sectors

Partners(?P) ∧ Confirmed_Locations(?CL) ∧ Confirmed_Sectors(?CS) ∧ has_operations_in(?P, ?CL) ∧ has_experience_in(?P, ?CS) → Possible_Partners(?P)

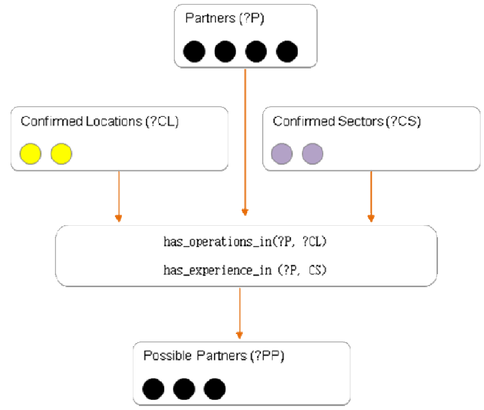

Figure 15. Rule5: Confirming Possible Partners

Figure 16. Results of Rule5: List of Possible implementing partners

Possible_Partners(?PP) ∧ Confirmed_Agencies(?CA) ∧ is_hired_by(?PP, ?CA) → Confirmed_Partners(?PP)

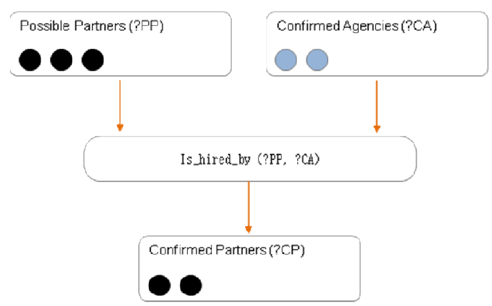

Figure 17. Rule6: Confirming Partners

Figure 18. Results of Rule 6: List of Confirmed Partners

5. Related Works

At the time of writing we could not find any publication which uses OWL/SWRL enabled computations for decision making in HC. For readers who would like to look at publications which analyze problems with the semantics of decision support system we suggest the work of Xiang et al. [25]. We agree that the lack of semantic representation and imperfection of software make many decision making solutions inefficient. Our solution is not a decision making system, but it helps in decision making by placing the semantics of the wider environment in HC within the taxonomies of OWL ontologies, which automatically enables reasoning. OWL enabled us to express complex relationships of information in HC fairly simply and achieve an efficient software engineering solution which may replace complex algorithms of traditional decision making. Huizhang et al. [26] proposes sequential group decision process for emergency response in order to address constant changes in situations IN the HC: uncertainty and the evolutionary character of HR. Their method deals with uncertainty by retrieving similar cases and applying the Bayesian Dynamic Forecasting Model to detect absent values. Our solution creates ad-hoc reasoning whenever a situation in HC changes: in OWL/SWRL computations we can infer classes and properties of ontology "as we go" and individuals can be asserted dynamically. Therefore in every moment in HC we have a model which can be run as many times as necessary (with different OWL structures/ values) for addressing resource allocation. The rich semantic of the model, enhanced with constant changes in constraints, compensate for missing values, because they may be found and interpreted through reasoning which is performed on an ad-hoc basis. The work of Shi et al. [27] has a few interesting ideas on how to build an online crisis decision support system and their predictor of responding might be incorporated within our ontology. A humanitarian coordination architecture in [28] requires a universal net-centric information management tool which helps with reconstruction and recovery operations. It would work on the principle of having continuously updated information shared in HC. Our computational model could find its place in their context and the tool set. This FP7 proposal is promising and might change our perception of how to manage the information in HC.

Our proposal comes very close to ideas of collaboration and situation awareness from [19,20] We have addressed both issues though *situations* in HC which we describe with OWL concepts (classes, constraints and individuals). Reasoning upon these concepts with SWRL secure not only decisions, which can be used in resource allocation, but it also addresses a particular situation at the time. Collaboration awareness is implicit in our model through the choice of OWL classes and their hierarches. However, they are always domain and situation specific and thus situations/collaboration awareness in HC are interrelated concepts.

If we wish to address the issue of risks and decision making in HC as debated in [29,30], we should extend the basic OWL classes with the semantic which manipulates risk management in decision making in HC such as: reluctance to act on uncertain probabilities, distortions of incentives to take care due to moral hazards, imperfect learning and social adaptation such as herd-following and group-thinking, and forecasting and coordination of individual behavior. They are considered in our future work.

6. Conclusions

In this paper we give a snapshot of ideas on how to support decision making in HC at the level of coordinating bodies. We adopt the coordinated needs assessment in decision making and use OWL/SWRL enabled computations to assist decision makers. This work is an excerpt of our long term interest in managing and exploiting data in HC and building modern software applications for the purpose of securing more efficient HR [21-24] We have tackled the problems highlighted in the Problem section and the OWL/SWRL enabled solution has been implemented as a Java based application which can run on any machine. Minor changes will be needed for adapting it to Android environments. The reader might ask questions related to the availability of data required by ontologies. There are numerous ways of feeding our ontological model. It could be through (i) direct transfer of information from the existing information system [31] or (ii) modern user interfaces which can also support voice [32] or (iii) direct, manual assertions which can happen at any time and at any place using any device [33]. It remains to be seen whether the shift towards coordinated needs assessment in decision making and the use of evidence in HR in general will hold. Modern software technologies will play important role in addressing both of them.

References

[1] Kari, J., "Making Sense of Sense-Making: From Metatheory to Substantive Theory in the Context of Paranormal Information Seeking", Workshop on Theoretical Stands in Studying Library and Inform. Institutions, Oslo, Norway, 1998.

[2] Pollack-Johnson, B., and Liberatore, M.J., "Incorporating Quality Considerations into Project Time/Cost Tradeoff Analysis and Decision Making", IEEE Trans. on Engineering Managm., 53(4), 2006, pp. 534-542.

[3] Kozlowski, S.W.J., and Klein, K.J., A Multilevel Approach to Theory and Research in Organizations: Contextual, Temporal, and Emergent Processes. In K. J. Klein & S. W. J. Kozlowski (Eds.), Multilevel theory, research and methods in organizations: Foundations,

extensions, and new directions, Jossey-Bass Publisher, San Francisco, CA, 2000, pp. 3-90.
[4] Mackenzie, M.L., "A Theoretical Model of Managerial Decision Making and the Accumulation of Information", Proceedings of the 33rd Annual Meeting of the Northeast Decision Science Institute, NY, USA, 2004, pp. 261-265.
[5] Pollack-Johnson, B., and Liberatore, M.J., "Incorporating Quality Considerations into Project Time/Cost Tradeoff Analysis and Decision Making", IEEE Trans. on Engineering Management, 2006, pp. 534-542.
[6] Lee, M.D., and Cummins, T.D.R., "Evidence Accumulation in Decision Making: Unifying the 'Take the Best' and the 'Rational' Models', Psychonomic Bulletin & Review, 11(2), 2004, pp. 343-352.
[7] Balci, F., Simen, P., Niyogi, R., Saxe, A., Hughs, J., Holmes, P., and Cohen, J.D., "Acquisition of Decision Making Criteria: Reward Rate Ultimately Beats Accuracy", Attention, Perception & Psychophysics, 73(2), 2011, pp. 640-657.
[8] Bajoria, J., "Improving UN Responses to Humanitarian Crises", UN Chronicle, United Nations, 2001.
[9] Darcy, J., and Hofmann, C.-A., "Humanitarian Needs Assessment and Decision-Making", Humanitarian Policy Group (HPG) Report, Overseas Development Institute, London, UK, 2003.
[10] Darcy, J., and Hofmann, C.-A., "According to Need? Needs Assessment and Decision-Making in the Humanitarian Sector", Humanitar. Policy Group (HPG) Report, Overseas Develop. Institute, London, UK, 2003.
[11] Darcy, J., Stobaugh, H., Walker, P., and Maxwell, D., "The Use of Evidence in Humanitarian Decision Making", Learning Paper, Tufts University, Somerville, USA, 2013.
[12] "Promoting Innovation and Evidence-Based Approaches to Building Resilience and Responding to Humanitarian Crises", Strategy Paper, Department for International Development, London, UK, 2012.
[13] Harmer, A., and Cotterrell, L., "Diversity in Donorship: The Changing Landscape of Official Humanitarian Aid", Humanit. Policy Group (HPG) Report, Overseas Development Institute, London, UK, 2005.
[14] Bradbury, M., Hofmann, C.-A., Maxwell, S., Venekamp, D., and Montani, A., "Measuring Humanitarian Needs: Needs Assessment and Resource Allocation in Southern Sudan and Somalia", Humanitarian Policy Group (HPG) Background Paper, Overseas Development Institute, London, UK, 2003.
[15] Macrae, J., Harmer, A., Darcy, J., and Hofmann, C.-A., "Redefining the Official Humanitarian Aid Agenda", Article, Opinions Magazine, Overseas Development Institute, London, UK, 2004.
[16] "SWRL: A Semantic Web Rule Language Combining OWL and RuleML", World Wide Web Consortium (W3C), http://www.w3.org/Submission/SWRL/, 2004.
[17] "OWL Web Ontology Language Overview", World Wide Web Consortium (W3C), http://www.w3.org/ TR/owl-features/, 2004.
[18] "Description of W3C Technology Stack Illustration", World Wide Web Consortium (W3C), http://www.w3.org/ Consortium/techstack-desc.html , 2004
[19] Treurniet, W., Besseling, K.V.B., and Wolbers, J., "Collaboration Awareness - a Necessity in Crisis Response Coordination", Proceedings of the 9th Int. Conf. on ISCRAM, Vancouver, Canada, 2012, pp. 1-5.
[20] Collins, L.M., James E. Powell, J., Dunford, C.E., Mane, K.K., and Martinez, M.L.B., "Emergency Information Synthesis and Awareness Using E-Sos", Proceedings of the 5th Int. Conf. on ISCRAM, Washington, USA, 2008, pp. 618-623.
[21] Shamoug, A., and Juric, R., "Addressing Interoperability Though the Semantics of Information Highway in Managing Responses in Humanitarian Crises", Proceedings of the 8th Int. Conf. on ISCRAM, Lisbon, Portugal, 2011.
[22] Shamoug, A., and Juric, R., "Decision Making in Humanitarian Crises Based on Owl/Swrl Enabled Ontologies", Proceedings of the Conference on Society for Design and Process Science (SDPS), South Korea, 2011.
[23] Shamoug, A., and Juric, R., "Semantic Modeling of Decision Making for Humanitarian Response to Crises", Proceedings of the Conference on Society for Design and Process Science (SDPS), Berlin, Germany, 2012.
[24] Shamoug, A., Juric, R., and Paurobally, S., "Ontological Reasoning as a Tool for Humanitarian Decision Making", Proc. of the 9th Int. Conf. on ISCRAM, Vancouver, Canada, 2012.
[25] Xiang, Y., Zhang, B., and Zhang, B., "Research on Semantic Decision Support System", Proceedings of the World Congress on Computer Science and Information Engineering, Los Angeles, CA, 2009, pp. 687-691.
[26] Huizhang, S., Huang, W.W., Jidi, Z., and Tao, J., "A Sequential Group Decision Process for Emergency Response", Proc. of IEEE Int. Conference on Systems, Man and Cybernetics (SMC), Singapore, 2008, pp. 867-871.
[27] Xianghui, S., Bibing, D., Liping, L., Xiangchen, L., and Mi, S., "Construction of an Online Crisis Decision Support System", Proceedings of IEEE 2nd Symposium on Web Society (SWS), Beijing, China, 2010, pp. 383-387.
[28] Matarese, F., Di Crescenzo, D., Strano, A., Aligne, F., and Mattioli, J., "An Interoperable Reconstruction and Recovery Decision Support Tool for Complex Crises Situations", Proceedings of the 7th International Conference on System of Systems Engineering (SoSE), Genoa, Italy, 2012, pp. 525-530.
[29] Ahituv, N., Igbaria, M., and Sella, A., "The Effects of Time Pressure and Completeness of Information on Decision Making", Journal of Management Information Systems, 15(2), 1998, pp. 153-172.
[30] Cox, L.J., "Community Resilience and Decision Theory Challenges for Catastrophic Events", Risk Analysis Journal, 32(11), 2012, pp. 1919-1934.
[31] Shojanoori, R., Nemitsas, P., and Krishnamurthy, A., "Generation of Ontologies from Relational Databases: An Experience", Proceedings of the 11th Int. Conference on Integrated Design and Process Technology (IDPT), Taichung, Taiwan, 2008.
[32] Kataria, P., and Juric, R., "Creating Semantics from User Inputs through Ontological Reasoning", Proc. of the 15th Int, Conf. on System Design and Process Science (SDPS), Dallas, Texas, 2010.
[33] Shojanoori R., and Juric, R., "Semantic Remote Patient Monitoring System", Tele-Medicine and e-Health Journal, 19(2), 2013, pp. 129-136.