of this hero:Hazard. This could be a human or a computational agent.

- hero:description. (domain hero:Hazard ; range xsd:string) This property is used to describe the hazard.

- hero:affectedAssets. (domain hero:Hazard; range prov:Agent) Tis property is used to specify what type of entities (human or non- human) are a_ected by the hazard. Figure 2 is a graphical illustration of the properties of the HERO ontology.

5. Raw Data to Actionable Knowledge

This section will explain the importance of stating information need in order to drive data discovery and harvesting.

5.1 Stating Information Need

For raw data to be turned to actionable knowledge, the information need requires to be either implicitly or explicitly stated. Once that is done, the next step is the discovery of the data(sets) that will be useful in fulfilling that information need. Data discovery will need to be followed by methods of harvesting the data that have been identified.

5.2 Data Discovery and Harvesting

Data discovery is the process of searching for the datasets needed to satisfy an information need. At the present moment, the process of data discovery is a manual process of engaging the usage of a search engine, scouring web sites, reading news items, etc. Once the required datasets have been discovered, then these need to be harvested. Data harvesting is the process of ingesting a particular dataset into one's data space. The datasets being harvested will be of different formats and structures, and different harvesting methods need to be employed on a case-by-case basis. The harvesting ranges from manual download to utilising REST APIs. It could also involve different degrees of web and document (pdf) scraping.

6. Modelling a Developing Hazard - Migration

This section describes how HERO was applied to model data regarding migration between borders.

6.1 Modelling Migration Data

The EU surrounding compared with countries, the EU has always been a magnet for migrants. Since the 1990s, the EU has consolidated freedom of movement for its citizens and increased restrictions on the entry of non-EU migrants. Therefore, many migrants come into the EU via the sea. In the central Mediterranean region, Libya is one of the main transit routes for migrants, and the instability that ensued after the Gaddafi regime was toppled has made the Libyan state weaker, increasing the frequency by which migrants get to the EU by sea. Most of the vehicles used for these journeys are not sea-worthy which have led to many hundreds dying. For example, Fortress Europe reported that from 1988 to March 2012, 13,417 had died making these crossings [4].

Many of these vehicles come under distress at sea during these journeys, and some of their occupants resort to phoning the nearest Maritime Rescue Co-ordination Centre (MRCC), and in some cases they may get sighted by other sea vehicles, such as a national state's Navy patrol vehicles, large fishing vessels, etc, and the staff on these vehicles can call MRCC to report the sighting of a sea vehicle distress at sea. MRCC then broadcasts distress messages to other vehicles in the area that may be able to rescue the passengers of the distressed vehicle. These broadcast distress messages are called hydrolant messages. Hydrolant messages are navigational broadcast warnings promulgated by the Worldwide Navigational Warnings Service (WWNWS) to provide rapid dissemination of information critical to navigation and the safety of life at sea. Navigational Warnings are issued regularly and contain information about persons in distress, or objects and events that pose an immediate hazard to navigation [6]. These messages, used by search and rescue (SAR) teams as guides to locate and rescue the vehicle under distress, are mostly free-form texts to state the where and the what of the incident. These search and rescue efforts are mainly multi-party and multinational, having disparate systems. These free form texts are good for humans, but the systems involved in the process find them difficult to understand and parse. These hydrolant messages (an example hydrolant message is shown in Table 1) can be classified as being derived from human observations and logistical information, as enumerated in section 2.2.

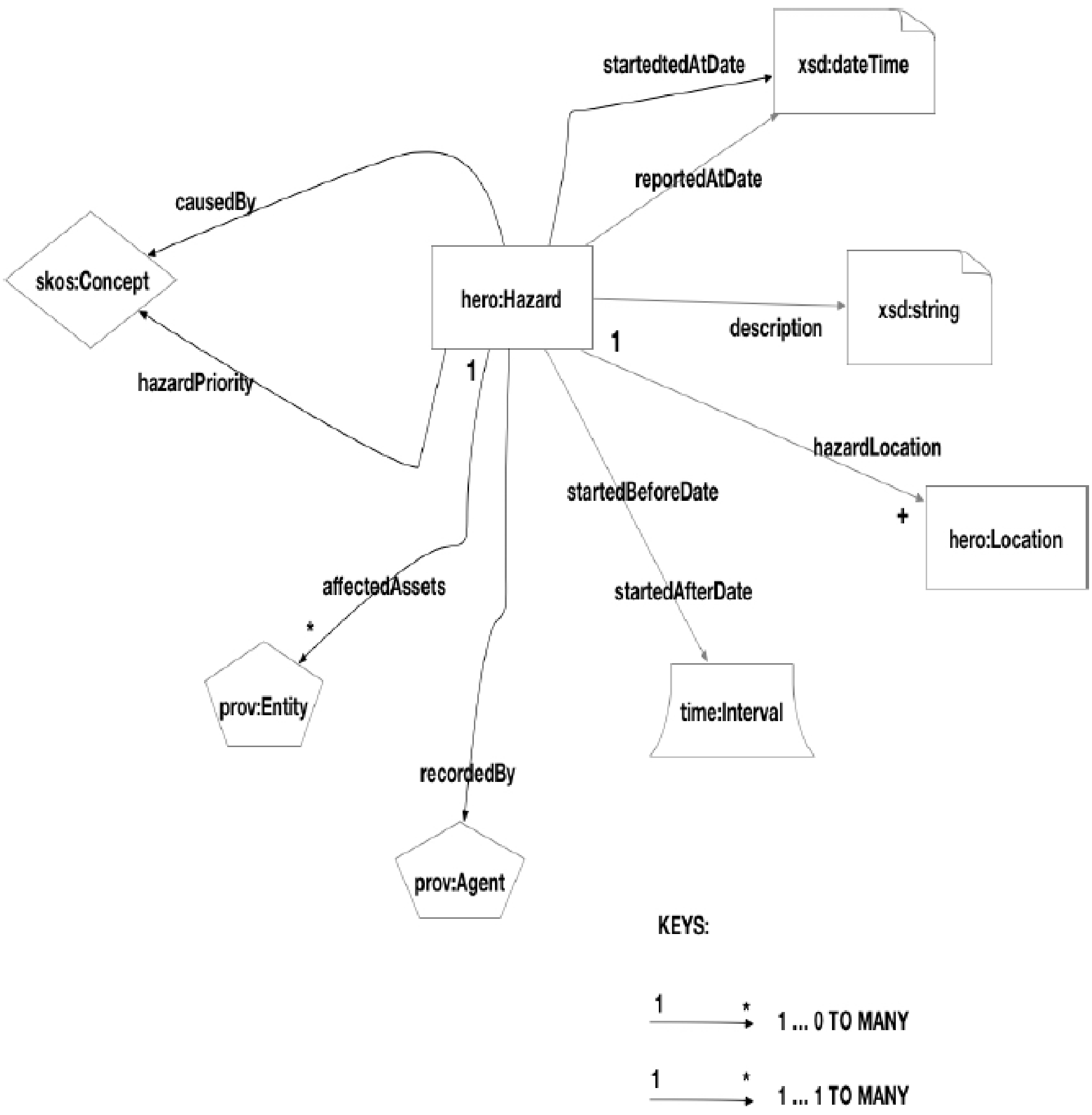

Figure 2: Properties of the HERO ontology

Table 1: DNC 08, DNC 09 Hydrolant Example

EASTERN MEDITERRANEAN SEA.
LIBYA.
DNC 08, DNC 09.
VESSEL, 130 PERSONS ON BOARD, REQUESTING ASSISTANCE IN 33-19N 012-39E AT 160330Z JUN.
VESSELS IN VICINITY REQUESTED TO KEEP A SHARP LOOKOUT, ASSIST IF POSSIBLE.
REPORTS TO MRCC ROME, INMARSAT-C: 424744220,
PHONE: 3906 5908 4527, 3906 5908 4409,
FAX: 390 6592 2737, 3906 5908 4793,
E-MAIL: ITMRCC@MIT.GOV.IT.
(160330Z JUN 2016)

6.2 HERO Ontology Applied to Modelling Navigational Hazard Messages

In this section, we will describe how we have used the HERO ontology to model hydrolant messages. We have used the Resource Description Framework (RDF) as the normal form for representing these messages. RDF offers many advantages, such as provision of an extensible schema, self-describing data, de-referenceable URIs, and, as RDF links are typed, safe merging (linking) of different datasets. We chose the RDF/Turtle representation of RDF triples for its compactness and clarity. We used Stanford's Parts-of-Speech (POS) tagger [8] to parse the texts in Table 1 to recognise the entities and their types. The POS tagger was able to recognise the following entities:

- "EASTERN MEDITERRANEAN SEA" as a location
- "LIBYA" as a location and a country
- The number value "130", and the entity type "PERSONS"
- Other location types, “33-19N” and "012-39E" as geographical entities
- "160330Z JUN 2016" as a UTC datetime format. (This date is read as 16 JUN 2016 at 03:30 UTC. The latter is not part of the POS tagger, but part of the hydrolant message type as provided by [6]).

Other recognised entities include `MRCC Rome', the Inmarsat, phone and fax numbers, as well as the email address.

The HERO ontology helped guide us to generate the RDF data for the hydrolant message of Table 1.

Table 2: DNC 08, DNC 09 Hydrolant description in RDF

```
:dnc08-dnc09 a hero:NaturalHazard,
hero:HealthHazard,
hero:NavigationHazard;
hero:hazardLocation
:dnc08-dnc09Location;
hero:priority :dnc08-dnc09Priority;
hero:reportedAt
"2016-06-16T03:30:00"^^xsd:dateTime;
hero:recordedBy :dnc08-dnc09Recorder;
hero:affectedAssets
:dnc08-dnc09AffectedEntity;
hero:description
"VESSELS IN VICINITY REQUESTED
TO KEEP SHARP LOOKOUT,
ASSIST IF POSSIBLE.
REPORTS TO MRCC ROME,
INMARSAT-C: 424744220,
PHONE: 3906 5908 4527, 3906 5908 4409,
FAX: 390 6592 2737, 3906 5908 4793,
E-MAIL: ITMRCC@MIT.GOV.IT."
:dnc08-dnc09Location a hero:Location;
dbpedia:place dnc08-dnc09Place;
juso:country dbpedia:Libya;
foaf:based near geo:lat="33-22N",
foaf:based near geo:long="013-23E".
:dnc08-dnc09Place a dbpedia:Place;
rdfs:label "EASTERN MEDITERRANEAN SEA".
:dnc08-dnc0Priority a skos:Concept;
skos:notation "9"^^xsd:integer.
:dnc08-dnc09AffectedEntity a prov:Entity;
prov:hadPrimarySource foaf:Person;
prov:value "120"^^xsd:integer.
:dnc08-dnc09Recorder a prov:Agent;
foaf:name "MRCC Rome";
foaf:mbox "ITMRCC@MIT.GOV.IT";
foaf:phone tel:390659084527,
tel:390659084409, tel:870-424744220,
fax:39065922737, fax:390659084793.
```

Table 3: Two location sighting DNC 09 Hydrolant Example

EASTERN MEDITERRANEAN SEA.
SOUTHERN IONIAN SEA.
DNC 09.
70 METER VESSEL, ORANGE HULL, 860 PERSONS ON BOARD, REQUESTING ASSISTANCE IN 36-37N 017-09E. VESSELS IN VICINITY REQUESTED TO KEEP A SHARP LOOKOUT, ASSIST IF POSSIBLE.
REPORTS TO MRCC ROME, INMARSAT-C: 424744220,
PHONE: 3906 5908 4527,
3906 5908 4409, FAX: 390 6592 2737,
3906 5908 4793,
E-MAIL: ITMRCC@MIT.GOV.IT.
(201422Z DEC 2014)

Table 4: Two location sighting DNC 09 Hydrolant description in RDF

```
:dnc09 a hero:NaturalHazard,
hero:HealthHazard,
hero:NavigationHazard;
hero:hazardLocation :dnc09Location;
hero:priority :dnc09Priority;
hero:reportedAt
"2014-12-20T14:22:00"^^xsd:dateTime;
hero:recordedBy :dnc09Recorder;
hero:affectedAssets :dnc09AffectedEntity;
hero:description
"70 METER VESSEL, ORANGE HULL, 860
PERSONS
ON BOARD, REQUESTING ASSISTANCE IN 36-37N
017-09E. VESSELS IN VICINITY REQUESTED
TO KEEP A SHARP LOOKOUT, ASSIST IF
POSSIBLE.
REPORTS TO MRCC ROME,
INMARSAT-C: 424744220,
PHONE: 3906 5908 4527, 3906 5908 4409,
FAX: 390 6592 2737, 3906 5908 4793,
E-MAIL: ITMRCC@MIT.GOV.IT."
:dnc09Location a hero:Location;
foaf:based near geo:lat="36-37N",
foaf:based near geo:long="017-09E";
dbpedia:place dnc09-1-Place;
dbpedia:place dnc09-2-Place.
:dnc09-1-Place a dbpedia:Place;
rdfs:label ``EASTERN MEDITERRANEAN SEA".
foaf:based near geo:lat="34-33N",
foaf:based near geo:long="18-02E".
:dnc09-2-Place a dbpedia:Place;
rdfs:label ``SOUTHERN IONIAN SEA".
foaf:based near geo:lat="36-33N",
foaf:based near geo:long="21-07E".
:dnc08-dnc0Priority a skos:Concept;
skos:notation "8"^^xsd:integer.
:dnc09AffectedEntity a prov:Entity;
prov:hadPrimarySource foaf:Person;
prov:value "860"^^xsd:integer.
:dnc08-dnc09Recorder a prov:Agent;
foaf:name "MRCC Rome";
foaf:mbox "ITMRCC@MIT.GOV.IT";
foaf:phone tel:390659084527,
tel:390659084409, tel:870-424744220,
fax:39065922737, fax:390659084793.
```

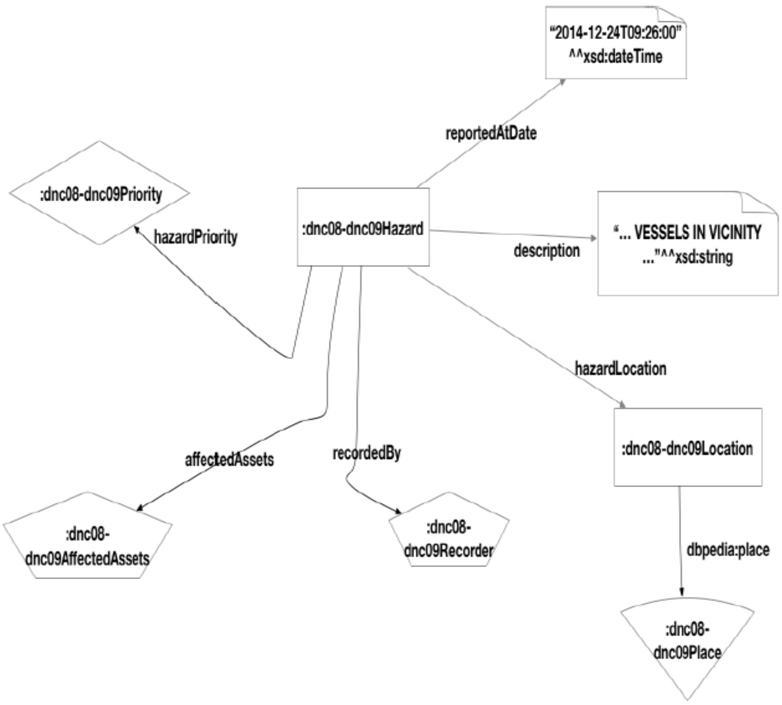

Figure 3: Resources for fulfilling the: dnc08-dnc:09 hydrolant message

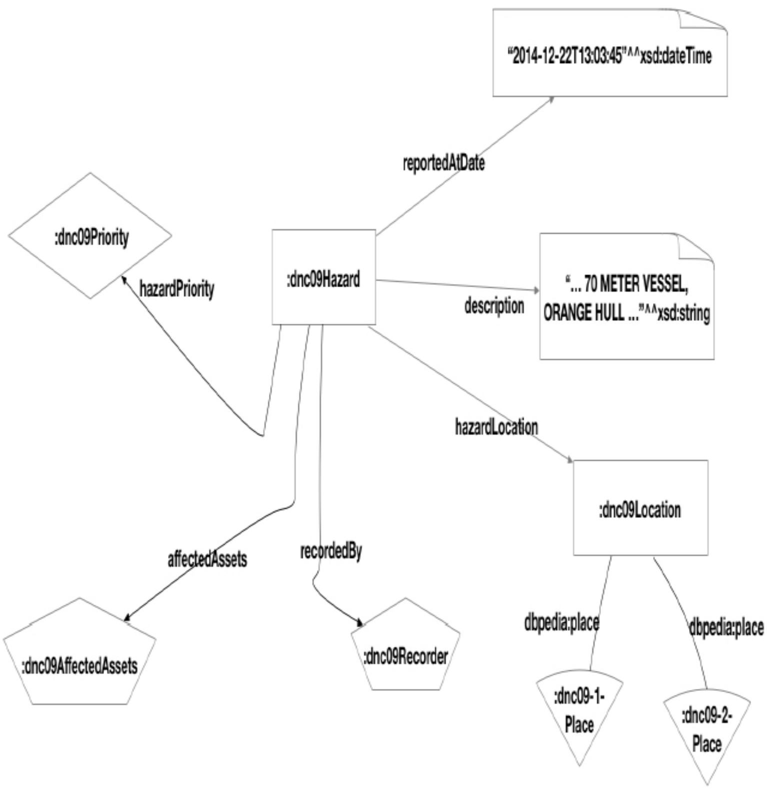

Figure 4: Resources for fulfilling the Two location sighting DNC 09 Hydrolant message

The generated RDF data is shown in Table 2. Figure 3 shows, graphically, the classes and properties (i.e. the resources) involved in the RDF data of Table 2. Another example hydrolant message is shown in Table 3. Using POS tagger helped to discern the entities in this message, enabling us to generate its RDF data (see Table 4), and Figure 4 shows a graphical illustration of resources involved.

7. Lessons Learnt

In section 2.1, we enumerated some of the challenges that need to be addressed for effective process and data fusion. Some of these challenges include:

- Enhancing the comprehension, visualisation and trust of the data
- The data, itself, should support interoperable and priority-sensitive features
- Lack of semantics in the data must be addressed

HERO ontology, and the generated RDF data from this ontology, has helped to solve some of these challenges:

1. Priority is regarded as a first-class type and, thereby, effectively modelled as a skos:Concept. By using a skos:Concept, it allows the priority property of a Hazard class to be inter-operable. A different organisation making use of the generated RDF data in Tables 2 and 4 can extend the priority, as modelled, to reflect their organisation's view of the incident's or hazard's priority

2. Having modelled these data as RDF, it provided a common vocabulary, or semantics, that can be used to improve situational awareness

3. By providing a common data semantics, applications can then be built to make use of these semantics that will enhance the dataset’s trust, visualisation and comprehension.

8. Conclusion and Future Work

This paper has described an ontology, HERO, used to represent hazards and emergencies. The aftereffects of emergencies are normally handled by multiple agencies with disparate systems. Having a common vocabulary to describe an emerging or existing emergency will allow these systems to easily interoperate, leading to more effective operations of first responders. HERO can be used to perform these roles.

In future work, we will investigate how data semantics and ontologies can be used to support the development of autonomous systems, by characterising autonomous systems' changing operational environments and using the languages of the Semantic Web to model and represent these environments.

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