Employing Geospatial Semantics and Semantic Web Technologies in Natural Disaster Management

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Abstract. In a natural disaster situation, it is crucial to orchestrate an efficient response, which prevents, or - at least - mitigates damages. Based on the assumption, that a well-informed decision maker can make the best decisions, s/he should have access to all available information. Thus, employing both internal and external data empowers decision makers. Since natural disasters are usually limited to a certain (previously unknown) area, it is of high importance to get to know about the local context of a disaster. Critical infrastructure, such as hospitals, energy supply, buildings with vulnerable beings (kindergarten, elder care, etc.) play an important role in crisis management. Nevertheless, a decision maker might not be aware of all of these places; yet, knowledge about these can often be found in external, public knowledge bases, such as Wikidata. Semantic Web Technology offers tools to integrate data from diverse data stores, offering a giant source of information. To improve situational awareness, this information should be tapped. By employing geospatial semantic features of knowledge bases, it is possible to integrate several data stores and only find information, that is valid within the range of a disaster and therefore of interest to a decision maker. The poster presents the integration of Wikidata as an external knowledge-base into a Decision-Support-System by using federated queries. Through employing geospatial semantic features, only relevant information is retrieved.

Keywords: Crisis Management, Geospatial Semantics, Situational Awareness, Federated Queries

1 Introduction

During a crisis situation, responsible managers have to take momentous decisions: while good decisions can mitigate or even prevent damage, bad decisions can allow or even amplify the extent. In a flood or large-scale fire event for example, authorities must decide if buildings in the endangered area need special protection or whether they have to be evacuated. Based on the assumption, that good decisions are likely to be made, when all available information is taken into account, a decision maker should have access to all available data sources to ensure situational awareness. Nevertheless, information overload must be prevented [1]. To do so, Decision Support Systems (DSS) disburden decision makers by (amongst other functionality) preprocessing and selecting relevant information and appropriately presenting their informational content [2]. We present an approach, in which an external knowledge base is integrated into an existing DSS through Semantic Web Technology whereas irrelevant information is sorted out by geospatial aspects.

2 Related Work

The poster presents an approach to retrieve data, based on geospatial semantics through federated queries, as well as visualizing the data and integrating it into a crisis-management context. Related work from all the named domains, preliminary work, as well as the project in which this approach was developed, is going to be presented below.

The discussed approach was developed in the context of the project beAWARE[1]. It's holistic approach yields into a single DSS, providing support over all phases of a natural disaster, including the forecasting and early warning phases until the end and reflection of such. Amongst other things, the beAWARE-platform comprises new tools for information retrieval and analysis, e.g. algorithms analyzing multi-modal input in form of pictures, videos, speech recordings and written texts from social media or messages directly sent to the platform. To ensure the correct understanding of the data, it is semantically integrated through the beAWARE Ontology, where the spatiotemporal context is saved. This ontology is presented by Kontopoulos et al. [3]. The interested reader can access the ontology on https://github.com/beAWARE-project/ontology.

In the presented approach, we utilize the Knowledge Base (KB) Wikidata, in which RDF-structured data is publicly made available. It offers data and information about a broad field, including places of interest during a natural disaster. Since it also contains geospatial metadata, it could offer information that is a priori not known to a decision maker in a natural disaster situation [4]. An often-criticized aspect of Wikidata is data vandalism requiring the verification of retrieved data [5].

For geospatial semantics, GeoSPARQL was established as a standard developed by the Open Geospatial Consortium. It defines a top-level ontology for spatial objects and geometries to explicitly capture the semantics of these. Additionally, it standardizes functions to support topological queries [6] [7].

Schulze et al. present an approach to combine datasets from different sources, such as mobile devices, Social Media and Semantic Web to empower authorities to detect natural disasters. The application is an event detection system for catastrophic events from large data streams. Through information collection, classification and semantic enrichment, the operator of the system shall gain situational awareness. By employing Linked Open Data, the expected usefulness of collected is calculated. Yet, geospatial semantics are not part of the approach [8].

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[1] https://beaware-project.eu/

3 Geospatial Semantics in Crisis Situations

In natural disasters, time is the enemy. Therefore, a decision maker has to gather all relevant information quickly to improve situational awareness and ensure a timely disaster response. Since the extent, urgency and need for action of a crisis is highly dependent on its geographic context, geospatial semantics offer a good filtering possibility to sort out irrelevant data. Semantic Web Technologies and geospatial semantics offer the possibility to exactly describe the user's needs and monitor different data stores for data of interest. Through geospatial semantics, a user can retrieve solely data close to a specific point or within a certain area.

In the following, the pipeline to retrieve data with the correct geographic context from an external data store is described. The usage of this data is simplified depicted in Fig. 1. During a crisis, heterogeneous data is collected through various sensors. The raw data is analyzed and semantically enriched with geospatial information according to the ontology. This data is stored internally and, by convention, considered trustworthy. Whenever an analysis tool identifies a need for action, an *incident report* is created in the beAWARE Knowledge Base. This incident is presented to the decision maker in the DSS (blue path). On request, the user can query for local context from the external data store Wikidata, whereas the location of interest is defined through the geospatial metadata of the *incident report*. Now, information about relevant structures close by and corresponding pictures are presented within a map in the DSS (orange path) and can be taken into account by the authorities. Through the identification of possibly endangered, so far undetected infrastructure, the decision maker can now coordinate rescue actions with more complete situational awareness.

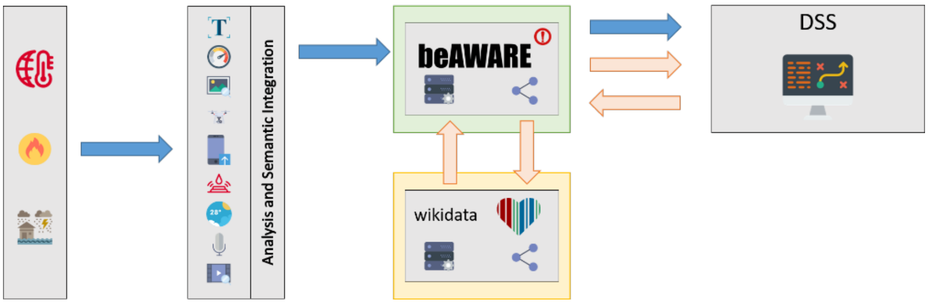

Fig. 1. A high-level view on beAWARE's semantic information retrieval

4 Querying and mapping information from different knowledge sources

To retrieve the situational context of an incident report, a query as shown below is used. The query is split in two sub-queries. Firstly, all incident reports in the internal knowledge base and their latitude *?lat* and longitude *?lon* are retrieved (line 3-11). The function STRDT in the SELECT function constructs a geo:wktLiteral, specified by the geoSPARQL ontology, as *?incidentReportLocation* (line 3-4). The second subquery is send to wikidata's SPARQL-endpoint and searches for all instances and instances of subclasses of architectural structures, that are within 1kilometer range of *?incidentReportLocation* (line 12-21).

```
SELECT DISTINCT ?incidentReportLocation ?name ?location ?place
?picture WHERE {
       {SELECT DISTINCT (STRDT(CONCAT("Point(", STR(?lon), " ",
STR(?lat), ")"), geo:wktLiteral) AS ?incidentReportLocation)
?name ?picture WHERE {
         ?incidentReport a beaware:IncidentReport;
         beaware:instanceDisplayName ?name;
         beaware:hasReportLocation ?location.
         ?location beaware:latitude ?lat;
         beaware:longitude ?lon.
         }
       }{SERVICE <https://query.wikidata.org/sparql> {
         SERVICE wikibase:around {
         ?place wdt:P625 ?location.
         bd:serviceParam wikibase:center
         ?incidentReportLocation;
         wikibase:radius "1".
         }
       OPTIONAL { ?place wdt:P18 ?picture. }
         FILTER EXISTS { ?place wdt:P31/wdt:P279* wd:Q811979 } .
         FILTER NOT EXISTS { ?place wdt:P31 wd:Q15893266 }.
       }}}
```

The retrieved results are depicted on a map (see Fig. 2), as shown below. *Internal knowledge*, integrated into the beAWARE KB is depicted in fully colored needle points. *External knowledge* coming from wikidata is depicted with a transparent needle point. The letter *p* indicates the availability of a picture showing the element at this position.

Fig. 2. Mapping data retrieved with geo-semantic queries in Openstreetmap

5 Conclusion

The proposed poster shows the experimental application of Semantic Web Technologies using federated SPARQL-queries with the geospatial functions of Wikidata in a natural disaster scenario. By integrating external knowledge sources, situational awareness can be improved and authorities can make better grounded decision, characterized by better management of available first responders and resources.

Still, the knowledge coming from an external source must be validated. Further, the geospatial functions of Wikidata are not fully GeoSPARQL compliant and limited; still, the expressiveness was sufficient within the presented application. In a next step, the retrieved information from external knowledge bases must be refined. Not only architectural structures, but also cultural events might be of interest for a decision maker.

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