SISel: Aviation Safety Powered by Semantic Technologies

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Abstract. Aviation safety is a complex domain with a potential of big losses in human lives and property. It encompasses not only media-followed accidents, but also minor incidents, regulation violations and, most importantly, their prevention. It is necessary to constantly monitor and improve the safety. In this paper, we show how we built SISel - a safety intelligence system based on a conceptual description of the domain. Semantic technologies played a key role in the development of this system – the conceptual model is based on the Unified Foundational Ontology, the data is stored in an RDF triple store and accessed using the ontological persistence framework JOPA. The system is already deployed at the Czech Civil Aviation Authority, where it is used to gather and analyze safety data.

Keywords: Aviation safety, Conceptual model, Ontology, Information system.

1 Introduction

Aviation safety supervision, carried out by the Civil Aviation Authority (CAA) in the Czech Republic, is a complex domain. CAA performs safety audits in organizations like operators or aerodromes, it receives reports about safety occurrences including accidents, rule violations and incidents. It also coordinates with the European Aviation Safety Agency (EASA). All these agendas were done separately, with almost no coordination between the corresponding departments in the CAA. Each department maintained its own documentation, often in different formats (mostly text documents or Excel files).

It is clear that the aforementioned agendas influence each other and their integration would provide a more general, unified view of the safety management and could lead to improvements in the area. Our research group at FEE CTU in Prague, together with the Department of Air Transportation at FT CTU in Prague and dolphin consulting s.r.o. embarked on a journey that would provide foundations for this unification.

We developed SISel – a safety intelligence system, which unifies some of the agendas of CAA and provides a more complex overview of the domain. In this paper, we briefly introduce SISel and show how semantic technologies helped in creating the system.

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2 SISel

SISel is a safety intelligence system built upon conceptualization of the aviation safety domain developed with the help of domain experts and expressed using an ontology. The overall architecture of the system can be seen in Figure 1.

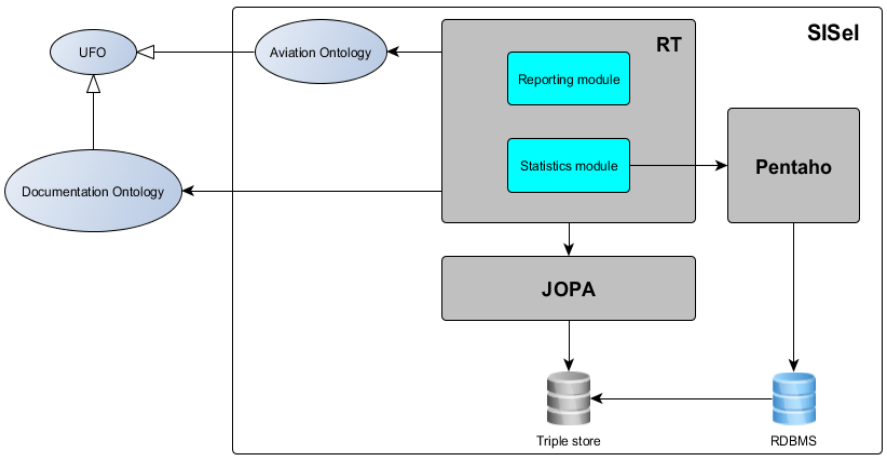

Figure 1. Overall architecture of SISel.

2.1 Conceptual Model of the Domain

The conceptual model of the aviation safety domain (the Aviation ontology in Figure 1) is built upon the Unified Foundational Ontology (UFO) [1]. It represents safety occurrences as UFO *events*, which are documented by *reports*. Reports themselves are a kind of *documents*. Events have *participating agents*, which can be for example persons or organizations, and a number of other data and object properties, for instance temporal and spatial information and sub-events.

This conceptualization allows a better understanding of the whole domain. Building the conceptual model based on the upper level UFO ontology makes it more interoperable. In fact, the conceptual model of SISel stems from the *documentation ontology* [2], which is not specific to the aviation domain, so reports from SISel can be integrated with other reports for example from the railroad transportation domain, provided their conceptualization is also built upon the documentation ontology. A detailed discussion of the aviation safety ontology can be found in [2].

2.2 SISel Reporting Tool

The main (or most visible) part of SISel is the Reporting Tool (RT). It is a safety reporting information system built on top of the conceptual model of the domain. The RT supports several kinds of reports:

- Occurrence reports – reports of safety occurrence like bird strikes, separation minima infringements etc. (mandatory in the Czech Republic),
- Audit reports – reports of audits performed by the CAA auditors containing findings discovered by the audits and their corrective measures,
- Safety issues – reports of problematic data patterns. Safety issues are usually created based on occurrence reports or audit findings and represent patterns likely to be problematic for the aviation safety.

An important possibility of the RT is to model chains of factors. This is most relevant to the occurrences, where the factors represent events, which were a part of or did influence the occurrence. The RT contains a simple chain designer component, in which these events can be added, arranged and connected using links representing relationships such as causality. Detailed information about the events can then be filled in. SISel RT uses the context of the type of the occurrence (or event) to require only relevant information (this relevance is determined by domain experts). To support this kind of dynamic selection, the RT uses forms generated from a declarative ontological description. This means that various kinds of events provide the user with different forms. Neither the chain designer, nor the dynamic forms are supported by reporting tools provided by EASA.

The RT allows standard report management and editing functions. In addition, it allows importing the reports from the email box, which receives occurrence reports from participants in the Czech aviation and occurrence and audit reports from the European systems ECCAIRS [3] and SAFA[1]. These reports can also be manually imported into the system. Another possibility is to synchronize the reports directly with the ECCAIRS system.

SISel also contains a statistical module, which is built using the open-source Pentaho business intelligence platform. The data is exported into Pentaho's database every night. Analytical dashboards created by dolphin consulting s.r.o. are then populated by the exported data. These dashboards include statistics on the frequency of occurrence types, the average severity of occurrences, the most frequent factors etc.

Semantic Technologies in SISel

As we have already mentioned, the conceptual model of the aviation domain is in fact an ontology. We use this ontology to generate portions of the object model of the reporting tool.

The domain also contains a number of taxonomies and predefined value lists, for instance there are predefined sets of occurrence categories and event types. All these value lists have been transformed into an RDF form and stored in a triple store. There is an internal service, which uses SPARQL queries to retrieve relevant lists of possible values from these value lists. Output of this service is then used to populate selection and autocomplete components in the RT user interface.

[1] http://www.eraa.org/sites/default/files/SAFA%20Forum%202012%20EASA%20presentation.pdf, accessed 2017-06-13.

The RT is a standard web application written in Java using the Spring framework. It has a JavaScript-based user interface (UI), which communicates with the backend via REST services. Such setup is common in today's Java web applications. The unusual thing about the RT is that it is based on the ontological conceptual model and stores its data in an RDF triple store.

To access the data, the RT uses a framework called JOPA [4], which maps ontological data to a Java object model and vice versa. Thanks to JOPA, the overall architecture of the RT very closely resembles any other Java application running on top of a relational database. This makes the development and maintenance of the RT easier.

In addition, the form descriptions are also stored in an ontology and the form structure is sent to the client in the JSON-LD format.

3 Deployment

SISel is currently deployed at the Czech CAA. The CAA employees use it mainly to model factor chains of occurrences reported to them. The statistical reports from SISel are then examined by the Safety Action Group – a board of safety experts established at the CAA. The system imports several reports every day; usually they are received in the CAA's email box, which is connected to the SISel RT. The total number of reports in the system as of June 2017 is over 1700 and it has been in daily use for the last eight months.

4 Example

We shall illustrate SISel usage on a real world example which demonstrates the usual way CAA employees work with SISel. An accident report sent by the Air Navigation Services (ANS) of the Czech Republic was received by CAA via the dedicated email box. The email contained a file in the E5X format. E5X is a file format used by the European Co-ordination Centre for Accident and Incident Reporting Systems (ECCAIRS), which is a safety occurrence reporting system whose usage is mandated by EASA throughout Europe. Technically, E5X is a compressed archive which contains one or more XML documents.

SISel RT imported the report from the received E5X attachment. A responsible person at CAA then reviewed the report, conducted an independent classification of the occurrence and its severity and designed a chain of factors that contributed to the accident. An excerpt of data from the resulting report can be seen in Figure 2. Data from this report are then manifested in the output of the analytical module of SISel.

The accident was later investigated (completely independent of CAA) by the Air Accident Investigation Institute (AAII) and a report was published[2].

As was stated, EASA mandates use of ECCAIRS for safety occurrence reporting throughout Europe. Therefore, a report of the incident was also entered into ECCAIRS by the employees at AAII, who manage the ECCAIRS instance in the

[2] http://www.uzpln.cz/incident/506 (Czech only), accessed 2017-06-03.

Czech Republic. Since SISel supports integration with ECCAIRS, CAA inspectors are able to review the latest version of the report of the same occurrence in ECCAIRS and compare it to the version they created in SISel.

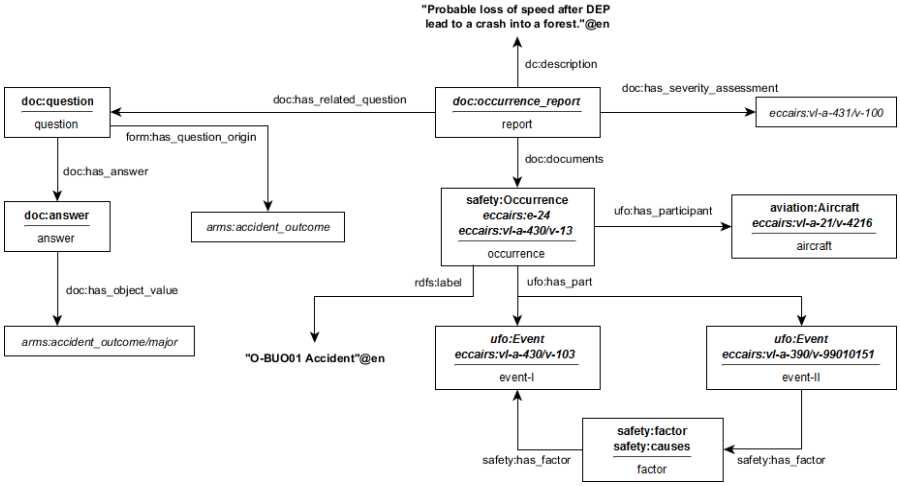

Figure 2. Report example visualization. IRIs are shortened, prefixes correspond to the respective ontologies/vocabularies. Bold labels above the horizontal line in nodes represent types of the instances, labels in italics refer to external vocabularies. Nodes without borders represent literal values.

5 Conclusions

We presented a case of semantic technologies being employed in an information system used on a daily basis by a non-academic organization. The system shall serve as a foundation of a larger ecosystem of applications and processes, which is planned for future development and will concern aviation safety in the Czech Republic. This ecosystem has also a potential of expansion into other domains and other countries.

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