Semantic Technologies

Project - Aviation Safety
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1 Description of domain: National Transportation Safety Board

The National Transportation Safety Board (NTSB) is an agency established in 1967, with the objective of conducting accident investigations from civil transportation [Boaa]. The NTSB checks and reports on aviation accidents and incidents, certain types of highway crashes, pipeline incidents, and railroad and marine accidents. If possible, the NTSB determines the probable cause of the accidents and brings out some safety recommendations, aiming to the prevention of future eventualities. The NTSB is located in the United States of America, working as an independent division from the government; it is not part of the Department of Transportation nor its modal agencies (including the Federal Aviation Administration). The NTSB has no regulatory or enforcement powers.

1.1 Aviation accidents and incidents

The NTSB owns a database with information about civil aviation accidents and incidents occurred since 1962 within the United States, its territories and possessions, and in international waters. When available, factual information is added; once the investigation is completed, the preliminary report is replaced with a final description of the accident and its probable cause.

Every year, the NTSB investigates about 2.000 aviation accidents and incidents, and about 500 accidents in the other modes of transportation. Only in 2013, the NTSB reported more than 34.000 fatalities among different types of transportation. For the aviation domain, this report included 443 aviation accidents (view figure 1) [Boab].

1.1.1 The investigative process

The NTSB begins the investigation of a major accident at the accident scene, as quickly as possible, assembling the broad spectrum of technical expertise needed to solve complex transportation safety problems. Having about 400 employees, the NTSB accomplishes this task by leveraging its resources, including the designation of other organizations or companies as parties to its investigations.

1.1.2 Investigations involving criminal activity

Whenever a criminal activity may be involved in an accident, it is possible that other agencies participate in the investigation. The NTSB does not investigate criminal activity; in the past, once it was established that a transportation tragedy is, indeed, a criminal act, the Federal Bureau of Investigation (FBI) becomes the leader investigative body, supported by the NTSB when needed.

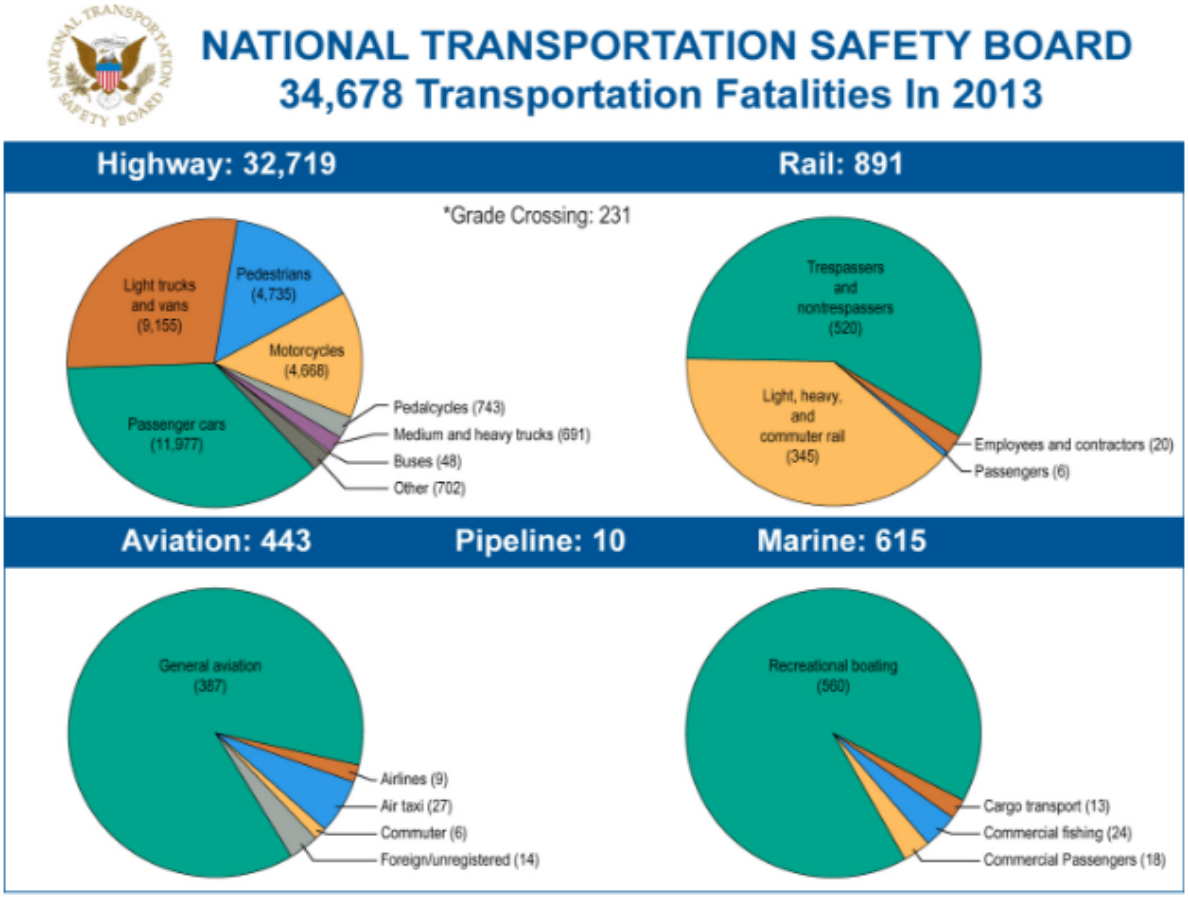

Figure 1: NTBS fatalities report on 2013 (preliminary estimates). Aviation data are from the NTSB, Marine data are from the Department of Homeland Security. All other data are from the U. S Department of transportation. Source: `https://www.ntsb.gov/news/press-releases/Pages/PR20150202.aspx`

1.2 Safety Recommendations

The most important mandate of the NTSB are the safety recommendations. The objective is to address safety deficiencies immediately, offering issues recommendations before completing an investigation. These recommendations are based on the findings of the investigation, indicating deficiencies that may not concern directly to the last cause of the accident.

1.3 Public Hearing

As a part of a major transportation accident investigation, the NTSB can hold a public hearing in order to gather the testimony of witnesses on identified issues. Also, the hearing allows the public to observe the progress of the investigation. Hearings are usually held within six months of an accident, but may be delayed in case there is a complex investigation involved.

1.4 Rest of the investigation and final report

The NTSB prepares a draft final report after more months of tests and analysis. Other parties do not participate in the analysis and report writing; however, they are invited to submit their findings of cause and safety recommendation proposals. Then, the NTSB deliberates over the final report in a public meeting in Washington, D.C. Non-Safety personnel, including parties and family members, are not allowed to interact during the meeting.

Once a major report is adopted at the meeting, an abstract of such report is placed on the NTSB web site; this report includes the conclusions, probable cause and safety recommendations.

1.5 Summary of NTSB investigations

The NTSB released the final summary of the civil aviation accidents in the United States occurred in calendar years 2012 to 2014 (view tables 1, 2 and 3). For 2012, the summary uses data updated on January 13, 2014; for 2013, data has been updated on February 18, 2015; and, for 2014, data has been updated on September 2, 2016. The summary combines information on accidents involving the following air carrier regulations:

- **Part 121: Scheduled**. It is for any domestic, flag or supplemental operation.
- **Part 135: On demand**. Part 135 operator rules govern commercial aircraft, such as non-scheduled charter and air taxi operations.
- **Part 91**: A Part 91 operator has regulations defined by the US Federal Aviation Administration (FAA) for operations of small non-commercial aircraft within the United States (although, many other countries defer to these rules as well). These regulations set conditions which the aircraft may operate, such as weather.

	Accidents	Fatal Accidents	Fatalities
Part 121 Air Carriers	27	0	0
Part 135 Commuter and On-Demand Carriers	39	7	9
Part 91 General Aviation	1.471	273	440
Total US Civil Aviation	**1.537**	**280**	**449**

Table 1: Summary of US Civil Aviation Accidents for Calendar Year 2012. Source: `https://www.ntsb.gov/investigations/data/Pages/2012%20Aviation%20Accidents%20Summary.aspx`

	Accidents	Fatal Accidents	Fatalities
Part 121 Air Carriers	23	2	9
Part 135 Commuter and On-Demand Carriers	51	12	30
Part 91 General Aviation	1.224	222	390
Total US Civil Aviation	**1.298**	**236**	**429**

Table 2: Summary of US Civil Aviation Accidents for Calendar Year 2013. Source: `https://www.ntsb.gov/investigations/data/Pages/AviationDataStats.aspx`

	Accidents	Fatal Accidents	Fatalities
Part 121 - Air Carriers	29	0	0
Part 135 - Commuter and On-Demand Carriers	39	8	20
Part 91 - General Aviation	1223	257	424
Total US Civil Aviation	**1.291**	**265**	**444**

Table 3: Summary of US Civil Aviation Accidents for Calendar Year 2014. Source: `https://www.ntsb.gov/investigations/data/Pages/AviationDataStats2014.aspx`

2 Our system proposal

2.1 Object-role modeling

The Object-role modeling (ORM) for the aviation accident database is shown in figures 2, 3 and 4. The central point of the model starts in the *Event* entity, which represents the event occurred that started an investigation.

- An *Event* (view figure 2) has an *InvestigationType* (this can be an Accident or an Incident); a *Date* in which the event occurred; a *WeatherCondition* (Visual or Instrument Meteorological Conditions); and a *ReportStatus* (this can be Factual, Foreign, Preliminary or Probable Cause). An *Event* also includes a *InjurySeverity*, indicating the highest level of injury among the involved parties.
- An *Event* occurs in a *Location*, in a *Country* or in an *Airport*. Also, an *Event* may include a position based on *Latitude* and *Longitude* values. Some events did

not occur on a specific *Country* (for instance, overseas), that is the reason to have different locations. In some cases, an event contains values for the three instances; however, in our final solution we prioritize *Airport* over *Country* and *Location*, because we already know where an *Airport* is located (including its *Latitude* and *Longitude*).

- An *Event* includes the report of one or many *EventCases* (view figure 3). An *EventCase* reports the following values: a *FlightPurpose* of the aircraft involved in some event; the *AircraftDamage* suffered by the aircraft (Minor, Destroyed or Substantial); the *FlightPhase* in which the aircraft was operating when the event occurred; if the flight was scheduled or not and the Federal Aviation Regulation (FAR) in which the aircraft was operating.

- An *EventCase* represents a possible aircraft involved in the *Event*. So, an *EventCase* is related to an *Aircraft* or an *AircraftModel* (view figure 4). The main difference is that an *Aircraft* is an *AircraftModel* with a registration number, while an *AircraftModel* is just an abstract model representation. An *AircraftModel* has a name, a manufacturer, number of engines, an engine type and a category (examples: Airplane, Balloon, Helicopter, Powered-Lift).

- Finally, an *EventCase* reports on the *AirCarrier* involved in the event. There are cases in which different carriers can have the same aircraft, that is the reason a carrier is not associated directly to an *Aircraft* or an *AircraftModel*.

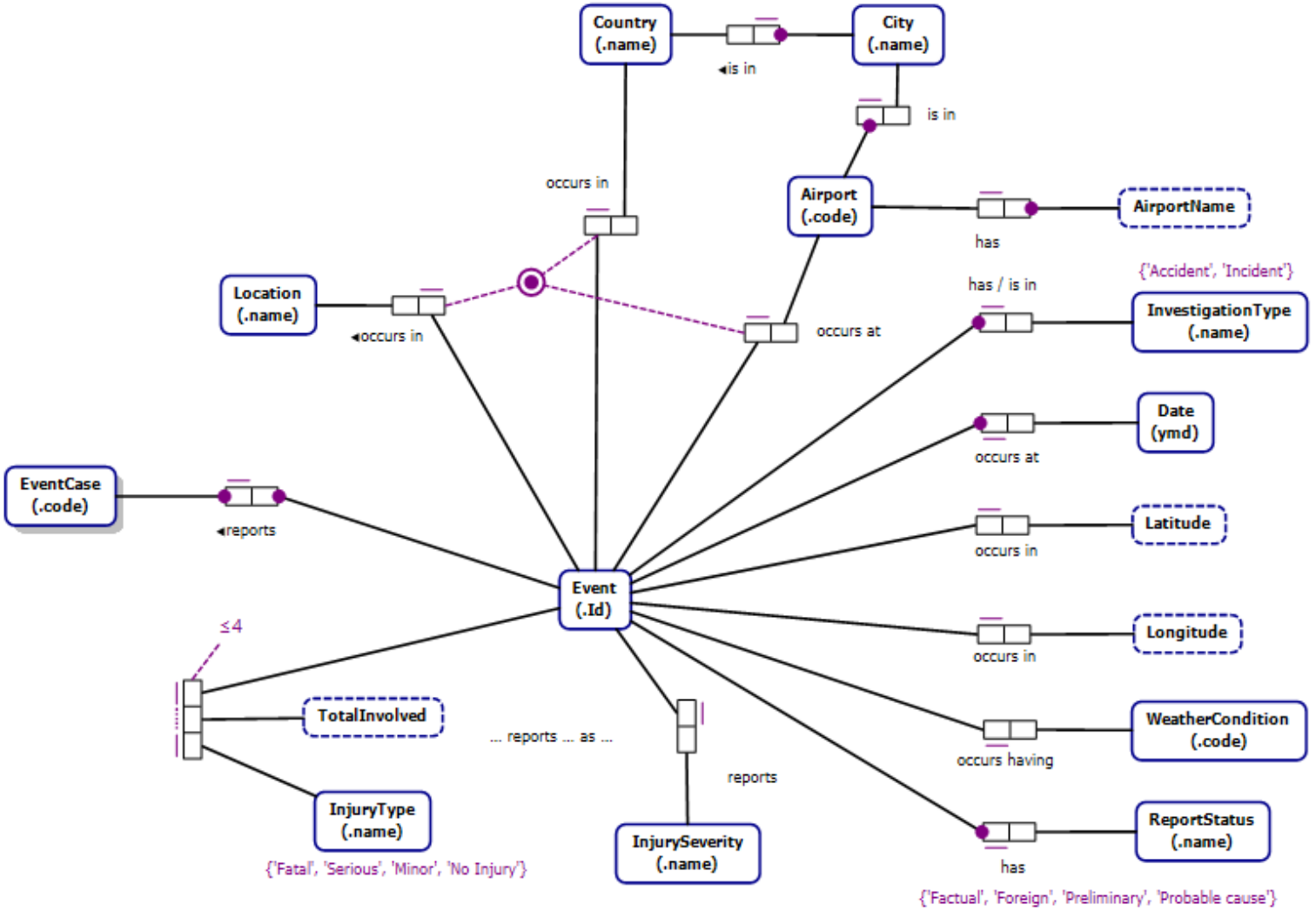

Figure 2: ORM for aviation events

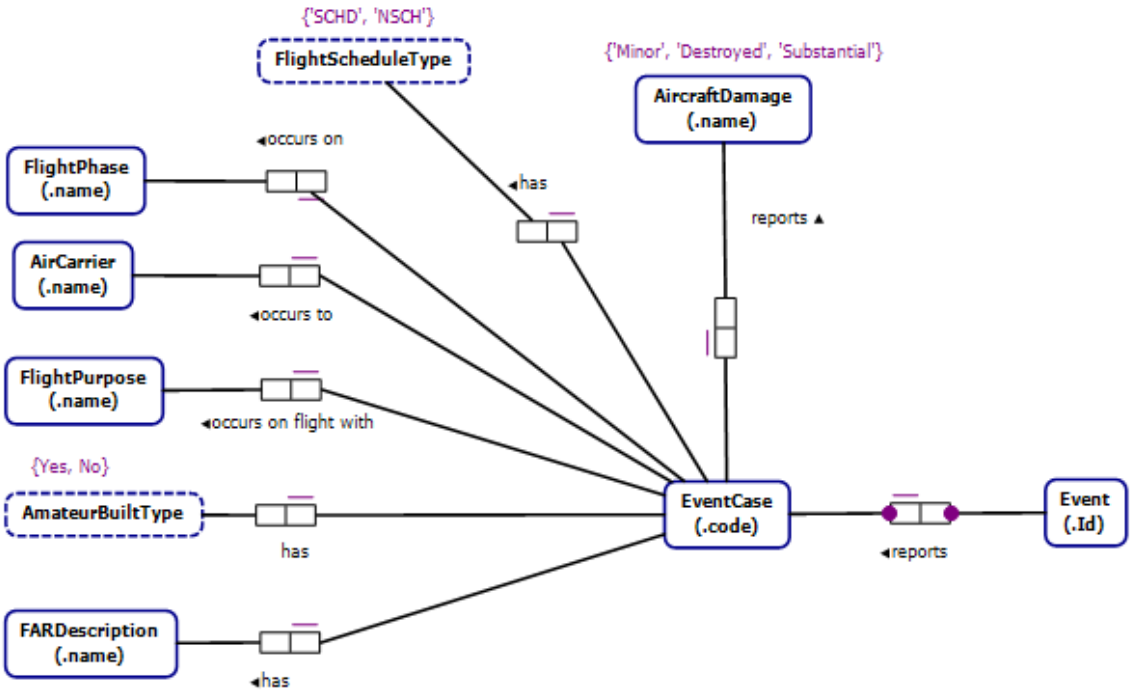

Figure 3: ORM for information registered in an event case

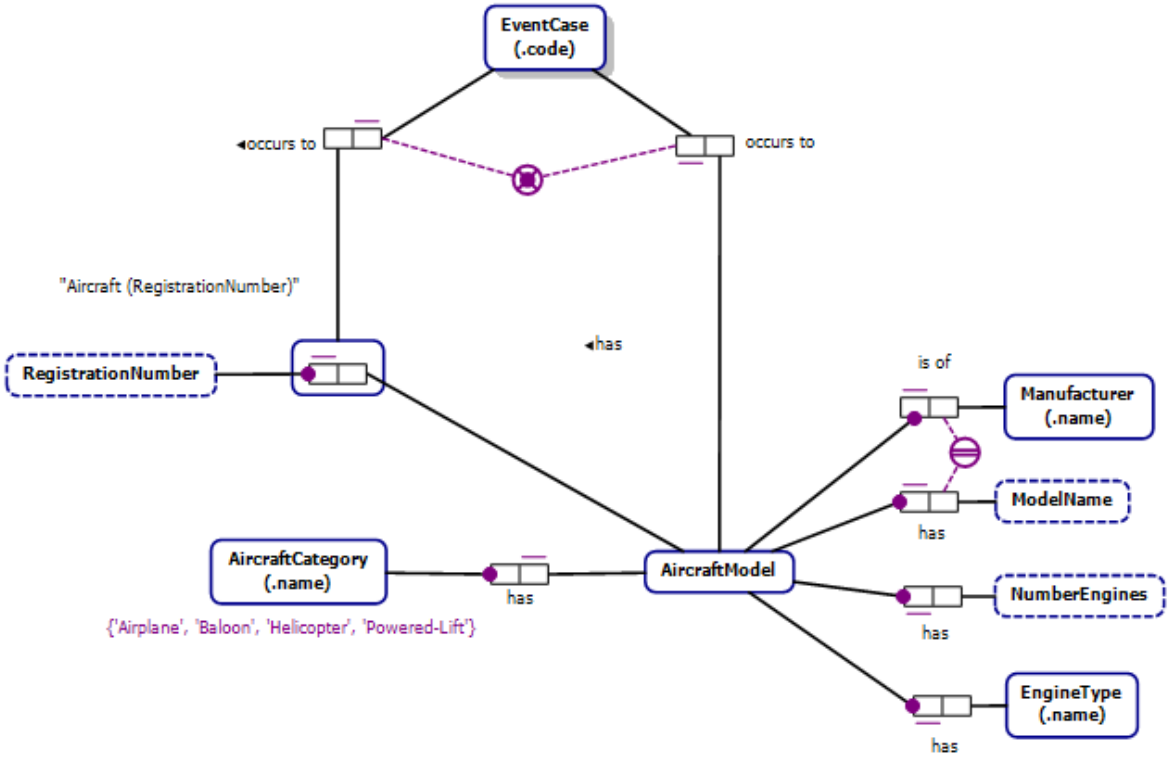

Figure 4: ORM for aircrafts involved in an event case

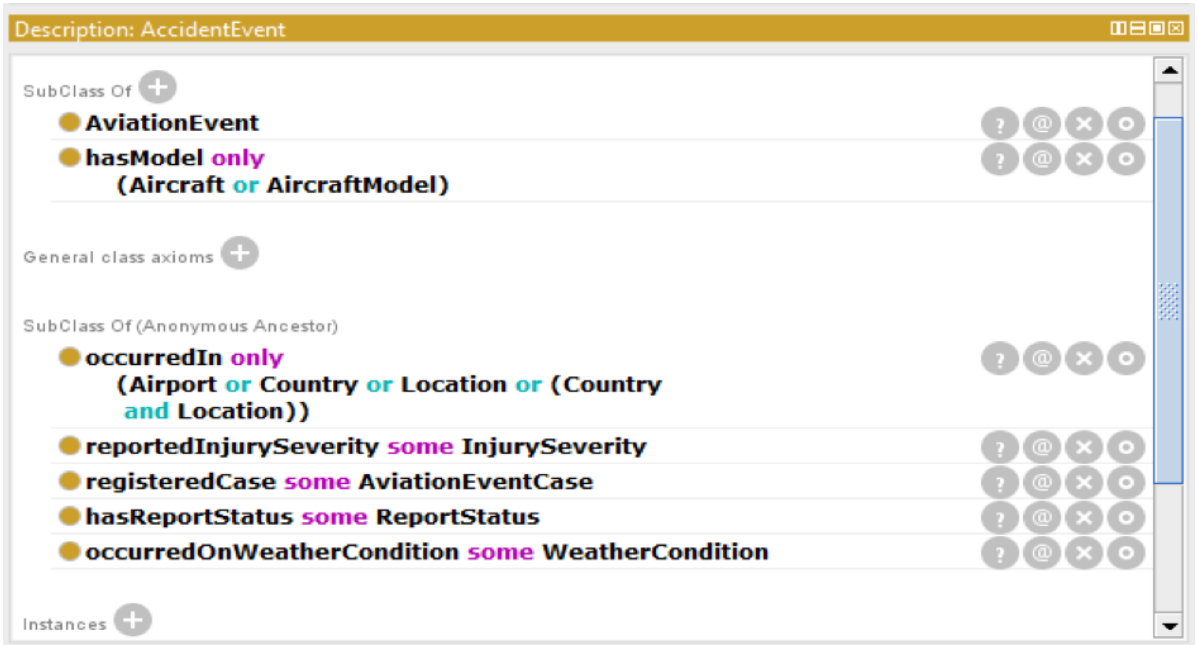

Figure 5: Entity *AviationEvent* and visualization of the relations and subclasses on Protégé

2.2 Model construction

We implemented an ontology based on the ORM presented on section 2.1. To generate the ontology, we used Protégé [Uni], allowing to create different entities (20 in total) and their relations. An example of the visualization of the entity *AviationEvent* is shown in figure 5.

2.3 Data storage and extraction

We stored data of the entities on a PostgreSQL database. Information is then extracted and used in the ontology with Ontop [Ont] mappings. For instance, to map information from an aircraft model, we queried the table "aircraft_model", and associating each column to different relations and properties in the ontology (view figure 6).

2.4 Data deployment

Finally, using the ontology and the mappings associated to the database, we created an Open-RDF endpoint. For this purpose, we applied an Ontop Virtual RDF store, importing the files generated by Protégé (*.owl* and *.obda* files).

2.5 Web application

"Aviation Safety" is a web application, implemented in Java using Servlets and based on Maven framework. This prototype uses single pages to search information about aviation events by querying the Ontop Virtual RDF store endpoint.

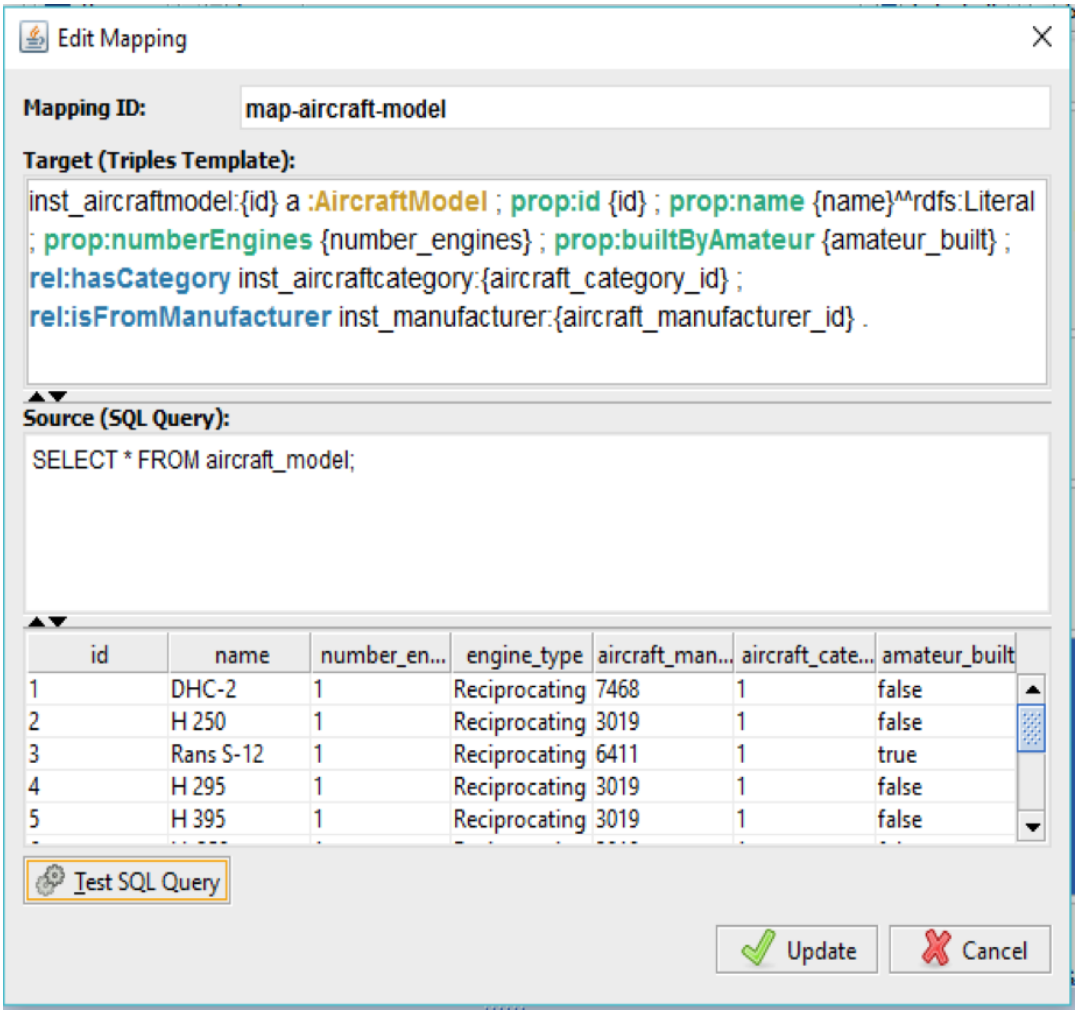

Figure 6: Ontop mappings on Protégé for table "aircraft_model"

The main functionalities of the application are:

- A dashboard, showing a map that links to the search page, filtering by the country that has been clicked. In the dashboard, we also present the summary of aviation events occurred on some countries (view figure 7). These values are static because the Ontop Virtual RDF endpoint does not support aggregation functions.
- A search page, displaying all the aviation events (view figure 8). For this prototype, we implemented only two filters: by country and by injury type.
- A display page, in which we show the information regarding an aviation event (view figure 9).

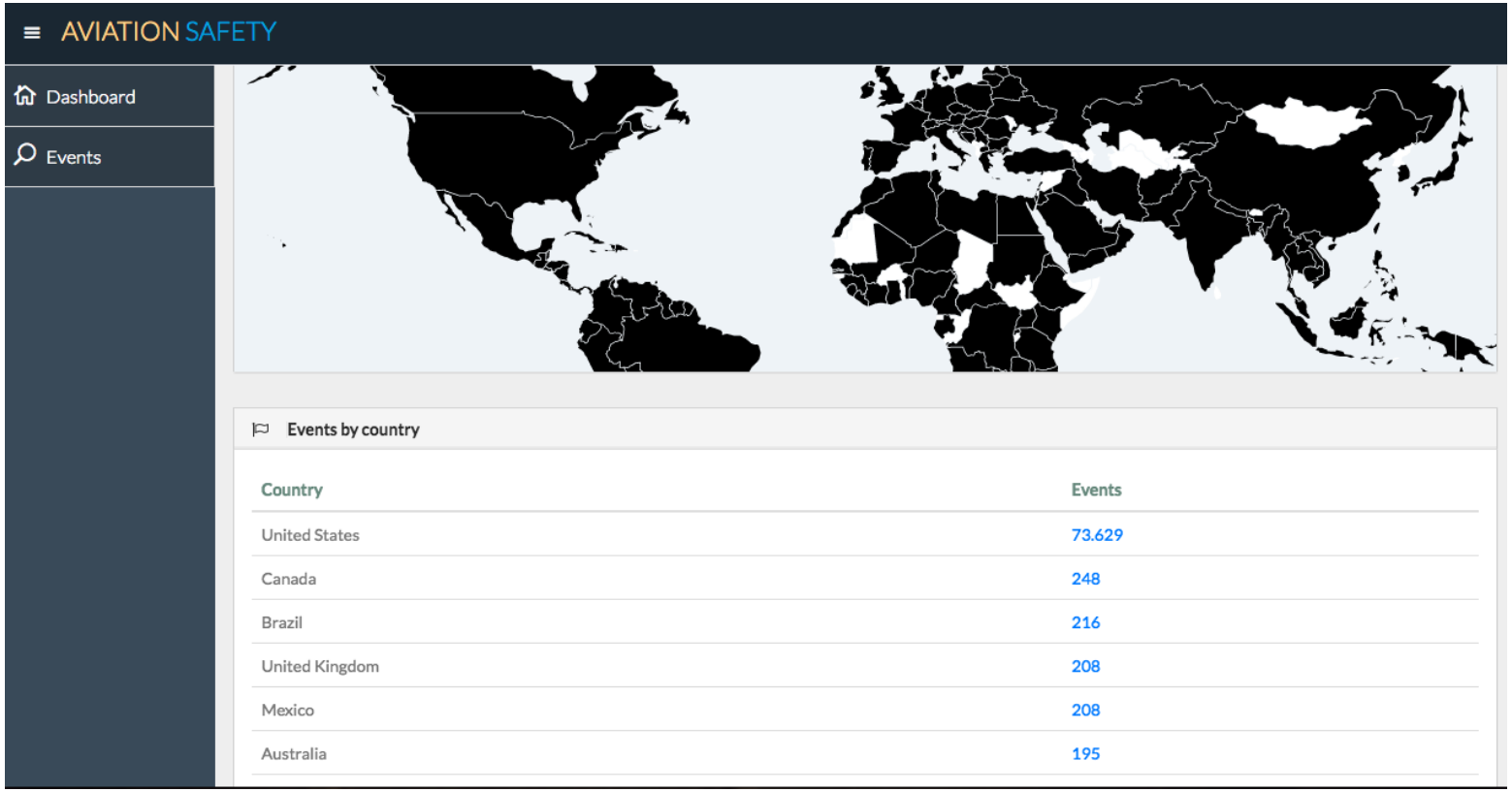

Figure 7: "Aviation Safety" application - Dashboard displaying list of countries and number of events

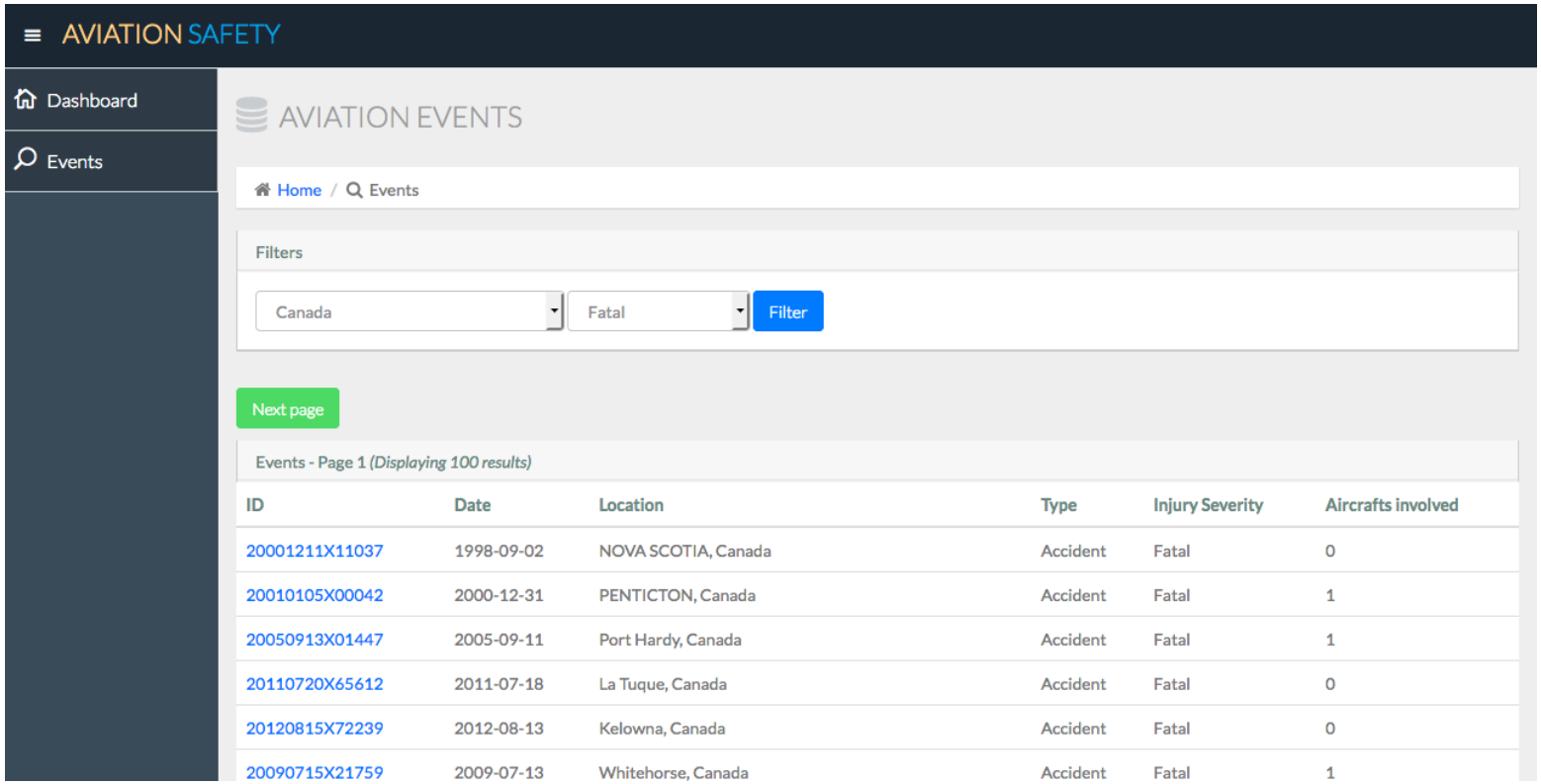

Figure 8: "Aviation Safety" application - Search aviation events. It is possible to filter data by country and injury severity

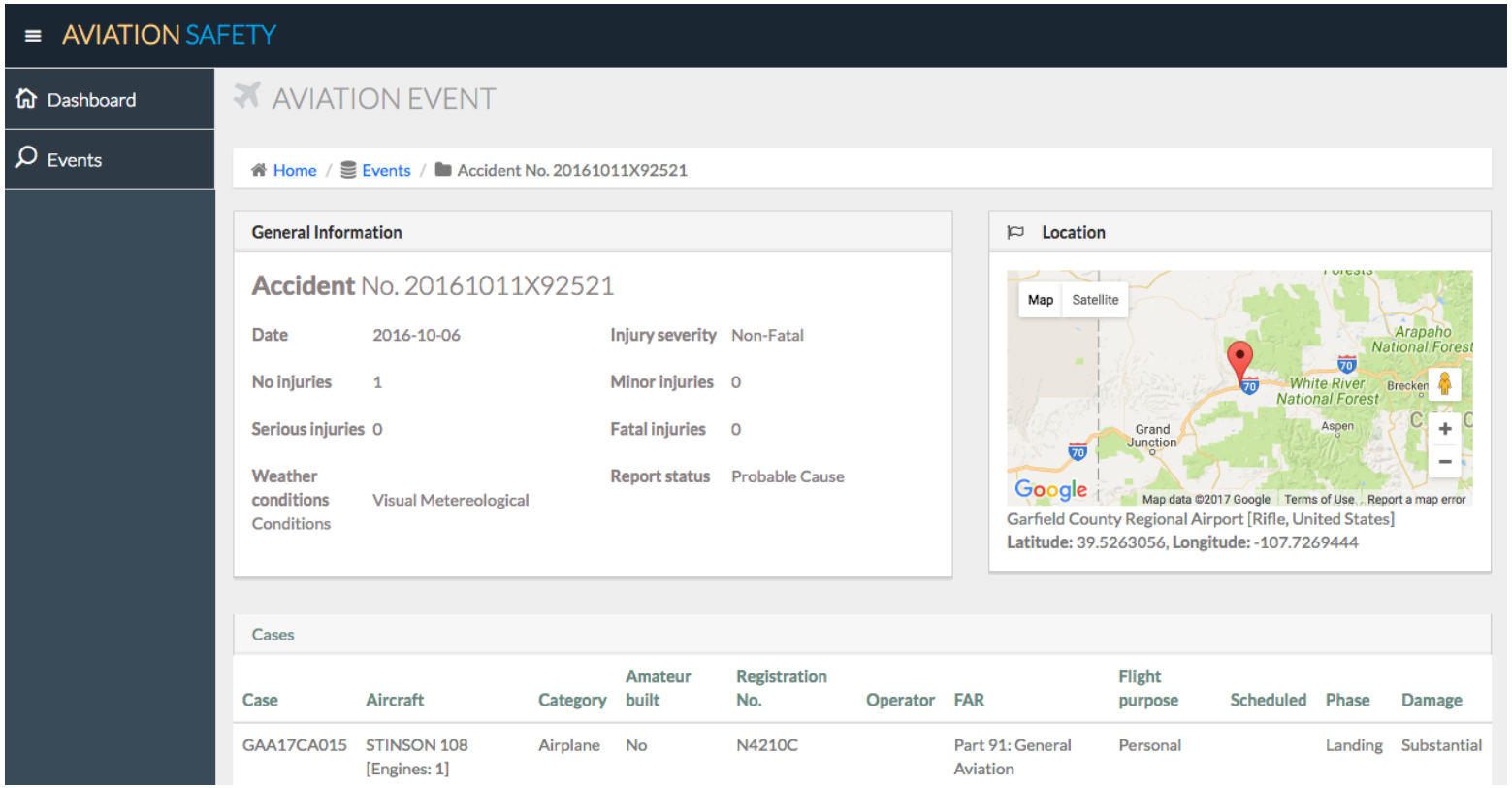

Figure 9: "Aviation Safety" application - Details of the aviation event occurred on Garfield Country Regional Airport (Rifle, United States) in 6th October, 2016

2.6 System architecture

The summary of the system architecture is shown in figure 10. As mentioned before, the ontology and the mappings are deployed on an Ontop Virtual RDF store endpoint, which is queried later on by the web application. The user accesses the application via a web browser.

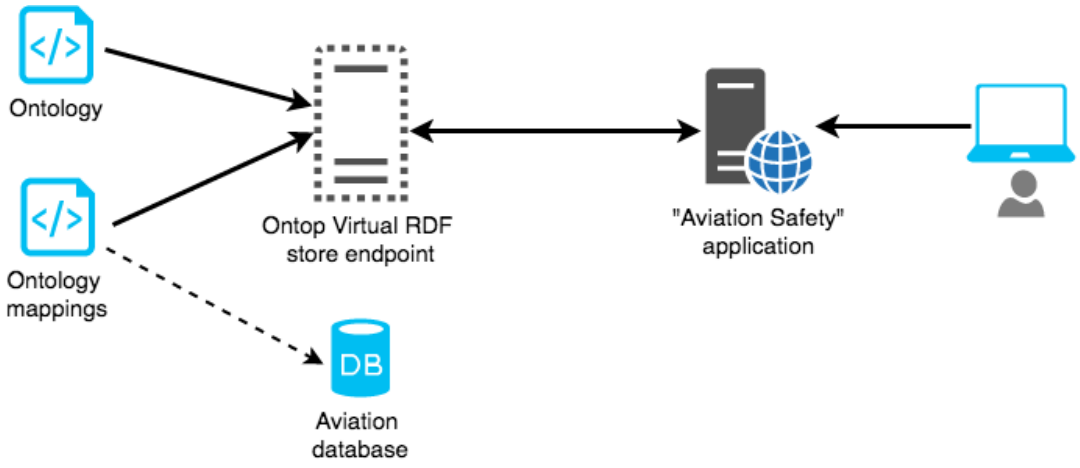

Figure 10: System architecture for the proposed system

2.7 Source code

Source code for our system proposal can be found on `https://gitlab.inf.unibz.it/aaronestrada/AviationSafety`.

2.8 Lessons learnt from the implementation

- Using semantic technologies allows to have a more structured and more understandable vision of our data sources.
- Querying data from semantic technologies is flexible and generally it responds quickly.
- Also, using semantic technologies, it is possible to integrate different available data sources, in contrast with other technologies where it is required to store them or access them, which leads to unnecessary adaptations.
- Tools like Ontop allows to keep data and structure in different layers, so it is possible to take advantage of database functionalities with the flexibility of semantic technologies.
- For our system proposal, some aggregations were needed; however, Ontop does not provide this kind of operations. So, the only way is to execute them using the database engine.

References

[Boaa] National Transportation Safety Board. *Aviation Accident Database & Synopses*. URL: https://www.ntsb.gov/_layouts/ntsb.aviation/index.aspx.

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