Modeling for Semantic Verification - Enhancement of Railway Infrastructure Planning

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1 Motivation

Planning a railway infrastructure is an extensive process. Placement and interaction of all infrastructural elements including security components like signals and level crossings has to be considered. Verifying the railway infrastructure against legal guidelines is an important task within this planning process. The verification purpose is to ensure a safe operation on the infrastructure. During the verification it is ensured e.g. that all elements are in correct positions, the spaces among them are sufficient and the alignment is correct. Today this verification task is mostly performed manually without any computer aid. The efforts presented in this exposé have the intention to automate the railway infrastructure verification process and formalize the exchange of railway planning data among different tools and authorities. Our focus lies on the development of a semantic model specifying railway infrastructure elements and their interrelations.

The railway infrastructure as well as the interaction and planning rules are modeled using the ontology description language OWL[W3C04a] and the Semantic Web Rule Language SWRL[W3C04b]. During the modeling process we enriched SWRL with railway specific enhancements while maintaining consistency and decidability.

As a transfer format between the infrastructure planning tools and the OWL model we use an open source XML-schema named railML[NHSK04]. We extended the railML schema in order to cover a majority of infrastructural elements and their attributes as they are defined in legal directives for railway planning.

2 State of research

The railML schema has been developed since 2001 by the railML initiative intending to establish railML as an open-source standard format for data exchange between diverse railway applications including tools for route simulation and disposition of trains as well as timetable systems and applications for railway infrastructure planning.
The main emphasis of our efforts lies on the *infrastructure* subschema of railML, which defines physical elements concerning the railway route. The definitions range from tracks, signals and level crossings to security related parts like train detection circuits or transponders for train deceleration and many more.

Software which supports infrastructure planning has no capabilities for verifying planning data semantically. The "BEST Editor" [Gmb09] is a standard application for infrastructure planning and simulation. However it does not provide any functionality for railway infrastructure verification against legal guidelines. The editor is equipped with a rudimentary export interface supporting an early version of railML, thus allowing the syntactic validation of the infrastructure data. Anyhow, a semantic verification cannot be performed neither within the BEST Editor, nor other tools, nor by focusing on railML only.

We favor an ontological representation of the railway infrastructure planning data using the web ontology language OWL. It is more expressive in comparison to a simple, syntax-only XML representation. Apart from that an OWL ontology can be enriched with semantical correlations in the plain model as well as by integrating complex semantic rules (SWRL) in horn clause syntax as antecedent-consequent pairs. This allows the creation of a realistic model which is in accordance with railway directive semantics and which can be used for the planning data verification task.

There are several approaches for infrastructural information representation in a domain specific ontological knowledge base. In [MFV07] a methodology for modeling urban infrastructures within an ontology is introduced. The work is mainly focused on defining an ontological model as a communication contract between the parties involved in urban planning processes.

*InteGRail* is a topic related project founded by the EU and has the ambition to homogenize the information retrieval and management within the railway world in order to enable optimization of decision making for improved performance on railway tracks. It uses an ontological model named ”Railway Domain Ontology” to solve the integration challenge of the railway environment. This model is applied allowing a predictive maintenance strategy in railway components[SFU08] in comparison to common maintenance strategies like RCM (Reliability Centered Maintainance). In the context of the *InteGRail* project there has to be mentioned another publication from Cristina de Ambrosi[AGT09] which discusses the integration of an embedded ontological system into railway vehicles. This system performs fault classifications within the vehicle. *InteGRail* is a good example for modeling railway related concepts using ontologies, but in contrast to our work in *InteGRail* the model is used as a data structure contract and we focus on the semantic verification of railway infrastructures.

3 Ambition

With our efforts we want to show that semantic modeling techniques can be applied to establish an automated railway infrastructure verification. We are developing a model which can be applied to represent legal railway guidelines as the verification basis. The
model has to be extensible and modular in order to be able to deal with different and incompatible signaling systems which can be found in the heterogeneous German railway industry. In addition we are extending the railML schema underlining the intention to establish it as a standard format for digital data exchange in railway applications.

4 Approach

Figure 1: Ontological Verification System

RailML is not sufficient to represent all infrastructural elements and their attributes requested by legal directives. We translate the hierarchical railway representation of the railML schema into an enhanced ontological, meshed representation, where the hierarchical structure is broken open. The original concepts and relations of railML remain, but are augmented with sophisticated interrelations. As a concrete example we can have a look at the concept "signal" in railML. A signal can be of the type main-signal or distant-signal among others. In the German railway infrastructure guidelines the correlations between main and distant signals are defined in a very detailed way. A distant signal, for instance, is always placed before a main signal in order to notify to the locomotive driver what he has to be aware of presently. The correct distances between the signals depend on the speed maximum of the track as well as on the visibility of the signals for example when they are placed in bends. These directives cannot be encoded using an XML schema, but the expressiveness of OWL and SWRL as ontology modeling languages permit the representation of such directives.

Figure 1 shows the layers of the verification system. At the bottom we find the class ontology which contains the railway concepts taken from the railML schema as well as categorization classes. These classes are used to mark verified elements like "[In]CorrectlyPlacedSignals" or "[In]CorrectTrackLength" etc. The rule ontology includes the class ontology and contains the rules representing the semantic correlation of the classes and properties. As a rule example the following directive shall be considered: A signal needs to be placed within the rage of the corresponding track it is assigned to. The SWRL rule defined in an abstract syntax is as follows:

\[
\text{Signal}(?s) \land \text{Track}(?t) \land \text{signalIsOnTrack}(?s, ?t) \land \\
\text{to}(?t, ?to) \land \text{from}(?t, ?from) \land \text{SignalPosition}(?s, ?pos) \land \\
\text{swrlb:greaterThanOrEqual}(?pos, ?from) \land \\
\text{swrlb:lessThanOrEqual}(?pos, ?to) \rightarrow \text{CorrectPlacement}(?s)
\]

Rule consequents (results) can be integrated into antecedents of other rules thus allowing
a hierarchization of rules and a reduction of complexity.

The individual ontology contains all concrete objects defined within the infrastructure planning tool. These objects are to be verified automatically against the German railway directives modeled in the class and rule ontologies. The individual ontology is generated applying an XSL transformation script to a railML document exported by the planning tool.

The RTVE Verifier performs the actual verification using the ontological knowledge base and generates a correctness report containing the verification results.

5 Status Quo

So far the ontological model is implemented for most parts. It is consistent and currently contains around 60 rules. Common railway infrastructure elements can be verified regarding their location, orientation and arrangement. Interlocking technologies, which also represent an important segment of railway engineering, are not covered by the ontological model yet. We are going to emphasize this part in our efforts, expecting them to have a high level of complexity.

References


