Knowledge Based Solution for Intelligent Verification and Validation of Interlocking Railway Systems

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Today's secure railway transportation management systems are employing more "intelligent", highly computerized technology but are still strictly dependent on the site-specific configuration of track layout, which follows different rules for different nations. An expert system model, which independently formalizes a railway network, focusing on railway terminals (stations) and including topological and functional aspects of track elements, enables verification and validation.

An interlocking system is an arrangement of signaling devices at track crossings or junctions that prevents conflicting movements of trains, and is designed to prevent the display of a signal for trains to proceed unless the route to be used is proven to be clear and safe. The control table rules the interlocking decisions process. Basically, it is a matrix composed of a row for each route and a column for each relevant track side device for that route [1].

Owing to the requirements of interoperability and high speed trains, European railway standards are being established, and complexity due to different kinds of interlocking systems is growing. Loosely coupled systems lead to high maintenance costs, which means that it is necessary to find a well-established shared configuration and operational system. Multiple solutions may be proposed to model a railway station, and the resources needed to validate and verify any solution or changes can time-consuming and unaffordable for single teams.

To tackle this problem, we studied and developed a new approach based on a KB (knowledge base) system. The overall system architecture (shown in Figure 1) is composed of three parts: a KB model, an input station (signal principles, specific track elements field, and track layout), and device specifications (track device status and commands configuration).
The KB model is based on an ontology which formalizes the relevant concepts of a track layout, e.g., track elements network and their related properties, such as train detector, signals etc.

The tasks of the KB interlocking model are: verification and validation; route request processing, validation of a track layout (and eventually suggesting missing elements); control tables generation.

To give an example, we could compile a station layout in the KB. Then, we could query the model to gain information about completeness and consistency of whole specification and of the elements adopted to configure the solution, exploiting routes or investigating which changes are needed to satisfy a specific interlocking principle, e.g., certifications. Using conventional procedures, the same actions would require considerably more effort, e.g., changing a safety rule means recompiling the entire control table including the related verification phases.

To build our ontology, we started by mapping the RailML infrastructure sub schema as a well-established domain of interest, identifying elements and their characteristics [2]. The RailML [2] is an XML schema related to railways domain composed of three subschemas: Infrastructure, Rolling Stock and Timetable. The infrastructure schema describes track positions according to nodes and branches modelling.

The initial prototype was unsatisfactory because the ontology was derived by simply mapping xml to owl thus obtaining a taxonomy i.e., no significant inferences would be possible. Therefore, the early model has been enriched by using the OTN (Open Transport Networks) for the topological aspects and SSN (Semantic Sensor Network) for modeling observations of event related to devices. OTN is a general purpose ontology oriented to transportation networks based on GDF (Graphic Data Format) which is a widely used binary data format for storing geographic data. The SSN ontology enables expressive representation of sensors, sensor observations, and knowledge of the environment. Despite to the large coverage the ontological model was not satisfactory and complete, thus other classes were added to improve the hierarchy of track elements, thus enabling inference and reasoning.
In order to validate the proposed ontology, data related to different railway stations formalized according to the rules of different countries (Netherlands, Germany and Italy) were loaded into the KB and tested.

The approach proposed introduces non-trivial advantages due to the formalized semantics, which, for example, can be used to infer new facts (e.g., use of a specific track device) or to prove safety properties (by means of the execution of semantic queries checking several kinds of verification and validation properties for completeness and consistencies), unlike state of the art formal specifications such as z-notation.

We chose OWL (web ontology language) as the modeling language and adopted Stardog as RDF-store and SPARQL end point for testing. The choice of Clark&Parsia's RDF-store was motivated by the fact that it incorporates a reasoner that implements integrity constraint checking. This feature is very necessary to handle the validation of a track layout. The choice of Stardog was motivated by the fact that with that solution it is possible to adopt a Close World Assumption for integrity constraints checking.

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Links

- RAISSS PROJECT: RAILWAY SIGNALLING SAFETY AND SECURITY http://www.disit.org/5481 ,
- TESYSRAIL PROJECT: http://tesysrail.it/en/

References

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[2] A. Nash, D. Huerlimann, J. Schutte e V. P. Krauss, «RailML-a standard data interface for railroad applications» Publication of: WIT Press, 2004.

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