INTEGRATING RAILWAY MAINTENANCE DATA
Development of a Semantic Data Model to Support Condition Monitoring Data from Multiple Sources

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Keywords: Railways, Data exchange, Domain ontology, Data interoperability, Condition monitoring.

Abstract: Railway networks comprise a large number of information systems, many of which are implemented by different stakeholders according to different design requirements, and in different ways. Owing to the safety-critical nature of these systems, data is rarely shared across boundaries, and the potential for re-use of information is lost. Using ontology, it is hoped that information from these systems can be extracted and shared, in order to facilitate better operational decision-making. This paper examines the aspects of data re-use likely to benefit the industry, and describes a railway condition monitoring ontology that is being designed in conjunction with several industrial stakeholders to improve operational efficiency.

1 INTRODUCTION

Railway networks around the world are of many different information systems, supplied and controlled by different stakeholders. Owing to the complexity of these systems, and the vastly different design approaches taken in each case, very little information sharing occurs, leading to duplication of data and sub-optimal decision-making in many areas. With railway usage having increased steadily in most countries over the past decade (Office of Rail Regulations, 2010), and with this trend set to continue, there is now a demand for greater and more intelligent utilisation of capacity and resources, and it is possible that much-needed efficiency gains in operation and maintenance of railways can be achieved through facilitating the sharing and exchange of information across the network.

This paper discusses the application of ontology for integrating day-to-day railway control data (specifically train locations and characteristics) with railway condition monitoring (RCM) system data. Various condition monitoring methods are in use throughout the world, including a number of points monitoring systems, signal lamp monitoring, and axle monitoring (for overloaded or over temperature axles). None of these, however, currently utilise the wealth of operational data available through other systems in order to provide context to information presented, and it is up to human operators to spend time researching associated train information should any of these systems present a fault - a task which is slow, error-prone, and costly. Through work undertaken with Invensys Rail Group (IRG), a manufacturer of railway signalling and control systems, it is the authors' aim to research and show that not only can relevant railway operations data be automatically presented with RCM fault notifications, but also that a common data model for various RCM systems can be established in the form of an ontology. This will be done through the development of a semantic data model to integrate data from Invensys Rail Group signalling and control systems with existing RCM systems currently in use on the railways.

1.1 Industrial Support

Invensys Rail Group (IRG) is a railway signalling and control company, whose products and systems are ubiquitous across railway networks throughout the world. This project is being undertaken with support from IRG, allowing knowledge gained throughout to be implemented in future products and systems. In addition to IRG's support for this project, Network Rail in the UK are also exploring the capabilities of more effective condition monitoring and data management in order to maintain the railway network more effectively, most notably through their Intelligent Infrastructure (IIS) project (Ollier, 2006).

Tutcher J., Roberts C. and M. Easton J..
INTEGRATING RAILWAY MAINTENANCE DATA - Development of a Semantic Data Model to Support Condition Monitoring Data from Multiple Sources.
DOI: 10.5220/0003661404420444
In *Proceedings of the International Conference on Knowledge Engineering and Ontology Development* (KEOD-2011), pages 442-444
ISBN: 978-989-8425-80-5

2 EXISTING SYSTEMS

Multiple RCM systems are currently in use across the UK rail network, to varying degrees of complexity. In modern signalling installations some power and track circuit condition monitoring capabilities are already built into control software, but the extent to which these are integrated with maintenance work is still limited. Beyond a signallers' warning to the train driver, no alerts are issued by the system itself. The types and capabilities of existing signalling and control systems vary widely across the UK rail network and throughout the world; as a result, while one benefit of an ontology-based system design is that multiple system architectures can be dealt with easily, it is likely that this project's scope will be initially limited to IRG's WestCAD system.

As part of the InteGRail project (Langer et al., 2008; Lewis et al., 2006), a European project aimed at exploring integration between railways, a number of ontology demonstrations were created showing the capabilities of the technology in the rail domain. A 'core ontology' was developed, encompassing high level railway infrastructure information such as routes and vehicle types, and several child ontologies designed to explore particular use cases identified initially. One such ontology looked at the handling of condition monitoring data from several existing data sources, and used reasoning in order to establish explicit and implicit fault conditions on a particular area of railway. Knowledge gained from the InteGRail applications will be built on in this project, specifically in the case of the railway condition monitoring system ontology design.

2.1 Wheel Impact Load Detection

Network Rail (owners and managers of UK mainline rail infrastructure) have 26 wheel impact load detection (WILD) systems in use on their network. These systems are placed at points along railway track to assess the physical condition of trains as they pass, in order to prevent further damage to railway infrastructure. Sensors measure stress/strain exerted on the rails to determine information about a vehicle as it passes. For each train passing a WILD site, date/time of passage, track and direction, wheel loads, and axle counts are recorded by the system and passed to a remote PC (AEA Technology, 2008). Using the current system, this information is passed to a central computer, and then distributed to regional centres for analysis using a piece of bespoke PC software. It is up to human operators in each location to interpret this data and decide which (if any) axles are damaging or dangerous, as well as to identify the actual trains passing the WILD system at any time ' identification is done based on known train movements using TRUST, a Network Rail run computer mainframe-run database (Network Rail, 2010) as well as through educated guesses of train types from axle counts. This is far from ideal, and the time taken to deduce train location and fault conditions is considerably longer, and less consistent, than should be possible using an automated ontology-based alternative.

3 ONTOLOGY APPLICATION

3.1 The Case for Ontology

Projects such as InteGRail (Langer et al., 2008) have recently shown applications of ontology across the rail industry, and specifically in handling various types of railway condition monitoring data (as in the wheel impact load measurement / hot axle box detection ontology created as part of that project). The InteGRail project successfully showed the inference capabilities of ontology technology within the field; this project aims in addition to explore data integration between train control systems and condition monitoring. A correctly modelled ontology system also has the more fundamental advantage of allowing data collected to retain its meaning and context, allowing more flexible querying and interrogation of data than is currently possible.

3.2 Data Exchange & Interoperability

A major advantage of an ontology-based approach to storing RCM data is that it can deal very well with heterogeneous data. Even across multiple systems designed by the same supplier, interpreting and acting on fault data from different types of monitoring equipment and sensors can be a challenge, and the structure of an ontology-based approach lends itself to coping with these scenarios very well. If the ontology is constructed such that states from condition monitoring equipment can be deduced regardless of system type (for instance inferring a 'fault' condition in each different type of system), communication is relatively trivial. Across existing multi-vendor systems, where data structures and communications protocols are likely to differ more, a semantic model allows data integrity to be maintained whilst building a common platform on which to reason and observe. Ontology also provides a flexible platform for expanding system reach further into the system's life, and will allow expansion into other areas of railway maintenance and operations without the requirement for a drastic restructuring of the system.

3.3 Reasoning & Inference

Using an ontology model to combine condition monitoring data with railway operations provides the potential for autonomous reasoning, removing the necessity for human operators to spend large amounts of time cross-referencing and checking raw data in order to determine and describe vehicle/infrastructure faults. This is likely to be a key benefit to railway operators, and an aspect of the system which will be developed in depth. A reasoner will allow, for example, the association between a vehicle's geographic location and an RCM fault value to be done automatically. This is one of the key benefits of using an ontology-based system to integrate data across the railway, and knowledge inferred through reasoning techniques is likely to be of great value to railway operators and other stakeholders.

4 A WILD ONTOLOGY

Initially, the development of a new ontology system to address the data integration issues discussed above will aim to capture information from the Network Rail WILD axle load monitoring system and combine it with train running data (such as vehicle locations and descriptions). It is proposed that such an ontology include knowledge of several aspects of the railway domain, as follows:

- Railway geography and network layout, in order to locate vehicles on track and RCM sensors. Invensys Rail's WestCAD system tracks train locations in discrete 'bays' along the track, based on data from railway track circuits or axel counters; the WestCAD data, or even track circuit data could be used to locate trains in an ontology.
- Railway vehicle knowledge. Train headcodes contain limited information about vehicle class (freight, passenger, high speed services); this information should be represented as such, with the possibility of being expanded upon using data available from other systems (in-cab diagnostics, train operator data).
- RCM knowledge such as WILD raw data, passing vehicle type, fault conditions, equipment characteristics, and equipment geography.

With these aspects correctly modelled, it is possible that rules created in an ontology reasoner will allow WILD data to be correlated to railway vehicles, and could also associate vehicle types with common line faults (for instance train bogie designs that are less reliable than others). Train speed and weight as acquired by the WILD system will also form part of the ontology, allowing speed profiling of services over long periods of time to be performed. Creation of this data model will allow the retrieval of WILD information with regards to specific trains, automatically, and will thus save the expense of needing human resources to verify all incoming RCM data. The eventual use of this system will add value to existing IRG products, and continued development of the ontology system should allow greater utilisation of the technology in the railway domain.

4.1 Future Development

It is important that the WILD system as described above be modelled in such a way that further development is possible, in order that many more sub-systems can be included and further knowledge inferred. It is the project's aim to use this ontology application as a basis for a larger railway systems ontology over the next two years, showing that further streamlining of railway data can be achieved across control, operations, and maintenance of the network. Further work will involve the inclusion of other railway systems data in the ontology, such as recorded vehicle 'black box' data (many trains record speed, location, and diagnostics information as they travel), and comprehensive timetable information. With the addition of these data sets, an ontology system will be able to perform further reasoning in order to contribute new knowledge to railway stakeholders.

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