“Using ontologies for decision support in large scale systems – InteGRail case study”

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Presentation structure

• Large-scale systems – the railway scenarios  
• Introduction to the EC FP6 InteGRail project  
• Capturing semantics  
• Requirements and architecture  
• Core and domain ontology  
• Prototype deployment  
• Standardisation and further work
Properties of large-scale complex systems

• A large amount of infrastructure
• Multiple stakeholders with different goals
• Complex contractual and physical interfaces
• Historically have collected data in silos
• Poor at strategic decision making
• Examples include:
  – railway system
  – power distribution system
  – defence industry

Railway industry structure

• The railway is:
  – Distributed
  – A closely coupled system
  – Multi-disciplinary in nature
  – Already collecting lots of SILO data
  – Has a large number of different asset (many simple)
  – Aims to increase ridership
  – Complex contractual stakeholder structure
  – Safety critical
A simple railway scenario

NEW INTERLOCKINGS IN CONTROL
(INTERNAL SYSTEM)

DUAL RUNNING INTERFACE TO EXISTING SIGNALLING
(OVERLAY SYSTEM)

OUTPUT TO SIGNALLING EQUIPMENT ROOM

OUTPUT TO SIGNALLING EQUIPMENT ROOM

PPP SYSTEM

CONTROL CENTRE

SIGNALLING EQUIPMENT ROOM

AUTOMATIC TRAIN PROTECTION EQUIPMENT
AUTOMATIC TRAIN OPERATION EQUIPMENT
INTERLOCKING EQUIPMENT
AUTOMATIC TRAIN SUPERVISION EQUIPMENT
EQUIPMENT SUPPLIED BY OTHERS

FIXED BLOCK PROCESSOR
OPERATIONAL DATA RECORDER
'BLACK BOX'
SIGNALLING EQUIPMENT ROOM
STATION MANAGEMENT SYSTEM (SMS)

FIXED COMMUNICATIONS UNIT
MCUs
ATP
ATO
APR Reader
Tachogenerator (Speed Sensor)
ATO Rx Antenna
FCU
LOCAL SITE COMPUTER (LSC)
Doppler
To ATO Tx Antenna

FIBRE OPTIC LINK BETWEEN WESTRACES

STATE OF RAILWAY EQUIPPED TRAIN REPORTS

Leaky Feeder
FIXED BLOCK PROCESSOR
KEY:

EMPLOYEE
OPERATIONAL DATA RECORDER
'BLACK BOX'
SIGNALLING EQUIPMENT ROOM
STATION MANAGEMENT SYSTEM (SMS)
More complex railway scenarios...

- **Infrastructure**
- **Vehicle**

**Video inspection:**
Track, surroundings, signal visibility, vegetation check, contact wire

**Position:**
D-GPS, automatic adjustment to objects (Indus/ATB, magnets, masts), manual setting

**Overhead line construction:**
Contact wire position: height & stopper, Mast position

**Rail surface:**
Rail crack, rail joint, burns, wear, deformation, corrugation, missing fasteners

**Rail cross section:**
Profile, railtype, rail height & head width, wear, gauge

**Track geometry:**
Gauge, level, alignment, superelevation, twist
Railway industry requirements

• Predict and prevent failures
  – No disruptions to service, increased dependability
• Reduction in life cycle costs
  – Mainly through better strategic decision making
    (e.g. better planning, monitoring degradation)
• Increased capacity
  – Better train control and traffic management
• European interoperability

** All require the integration of data **

Required outputs

• Total capability delivers value (i.e. high dependability)
  • People, processes and tools
• Implementation is a whole business problem, not just a computer or electronics problem...

- Raw Asset Data
- Data Processed in IT Systems
- Active Knowledge Management
- Dynamic Decision-Support Capability

Data gathering, transmission and storage
Data processing and visualisation
Deriving and automating knowledge
Delivering tailored, dynamic decision-support information
The InteGRail project

The InteGRail vision

InteGRail aims at creating a holistic, coherent information system, integrating the major railway sub-systems, in order to achieve higher levels of performance of the railway system in terms of capacity, average speed and punctuality, safety and the optimised usage of resources. InteGRail will propose new intelligent procedures and will contribute to the definition of new standards, in compliance with EC directives and Technical Specifications for Interoperability.
InteGRail background

State-of-the-art (?)
InteGRail background

- Euromain – European Commission funded project
- XML as standard for data interchange
  - Result: XML is not expressive enough – too ambiguous
- Some UK trains still operate with a ‘Euromain’ type XML data schema
- InteGRail – required specific scenario modelling for data
  - Capture of semantics is required to identify the scenario
  - Context Modelling

InteGRail

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Capturing Semantics

• UML Class Diagrams
  – Mapping required back to legacy systems
  – Forward transformation required for XML schema
    • At the time tools to automate this were still in development
  – UML represents data objects and relations but additional logic must be processed to identify context
  – If logic is captured programatically then the data becomes application specific
  – Not ideal for interoperability

Ontology?

• Machine interpretable meta-model
  – Capable of capturing the semantics to infer context
  – Widget X requires action A
  – Widget Y requires action B
• Ontology Web Language (OWL)
  – Extension of RDF
  – Directly addressable Web format
  – http://www.integrail.info/owl/railway/wheel
  – http://www.dft.test/owl/roadtransport/wheel
Ontology

- Description Logics – family of knowledge description languages (more expressive than propositional logic and more efficient than predicate logic)
- OWL can be extended with DL (OWL-DL)
- OWL can be used to create interface standard for IT systems:
  - That have different data models
  - That operate on different platforms
- Is this an appropriate solution for railway integration?
  - This was the research question

Specific Requirements

- IGR solution must enable simple subscription mechanism
- Must not alter stakeholders internal IT infrastructure i.e. firewall issues
- Platform independent
- Must be flexible to support the great variety of data in railway domain
Architecture

- Service Oriented Architecture
- Trend – deploying agents to collaborate to meet a goal
- Ahead of our time!
  – Research?

Intelligent Agents

Operator Agent
- Strategy
  - Planner
  - Task 1
  - Task n
- Constraint Solver
- Message Receiver
- Train Compositions:
- Allowed freight load
- Distributed Reasoning on Train-Preparation Ontology

Infrastructure Manager Agent
- Strategy
  - Planner
  - Task 1
  - Task n
- Constraint Solver
- Message Receiver
- temp. Capability and Capacity Constraints
- Sectional Domain KB

Distributed Reasoning-Services
Infra Knowledge e.g. Points etc.
Solution

• A distributed network of reasoning nodes
Subscription

• The interface between them was a Railway Domain Ontology (RDO)

Web Service

Agent A

Register Query \((t,f)\)

Agent B

Post result

Technology

• RDFXML / OWL
• RDO - the meta model for identifying context
• JENA – an API for interfacing with memory model and reasoner
• RacerPro / Pellet – reasoner apps
• Web Service
• SOA
• SPARQL query language
Subscription

Web Service

Register Query \((t,f)\)

Agent A \(\rightarrow\) Agent B

Post result

Semantic Stack
InteGRail: Distributed Semantic Nodes Service Oriented Architecture (SOA)

Need to model?

- What decisions are needed?
  - Fault detection & diagnosis
  - Maintenance
  - Asset management
  - Operational management

- Train data
- Infrastructure data
- TAF TAP/TSI (XML)
- RailML (XML)
Needs?

Railway Domain Ontology

• Requirement – compositional modelling
• The bigger the model, the longer the reasoning time required
• Compositional ontology – importing required ontology components ‘on the fly’
• Using existing upper ontologies - SOUPA
Existing Resource

Compositional Models

- Train Configuration
Compositional Models

• Vehicle Composition

Railway Ontology

• Monitoring Requirements
core:TargetSystem

core:Observation

d:TrainWithCriticalWILMStatus

core:Symptom

WILM:HighWheelForce

core:Fault

core:SystemStatus

Ontology

Instance

Train_Consist_1

Status_Train_Consist_1

Observation_TrainConsist_1

Fault_TrainConsist_1

WILM:CriticalWILMStatus

WILM:HighWheelFault

id:Train_Consist_1

wilm:Status_Train_Consist_1

wilm:Observation_TrainConsist_1

wilm:Fault_TrainConsist_1
Core Ontology

- Domain split into:
  - iMON – Intelligent Monitoring
  - iMAIN – Intelligent Maintenance
  - iMAN – Intelligent Management
- Therefore:
  - Ontologies for each aspect

Deployment

- Many partners with different requirements
- Different levels of complexity
- 3 scenarios
  - European Freight
  - UK passenger transport
  - High Tech/High Speed
Specific Requirements

• IGR solution must enable simple subscription mechanism ✔
• Must not alter stakeholders internal IT infrastructure i.e. firewall issues ✔
• Platform independent ✔
• Must be flexible to support the great variety of data in railway domain ✔
Standardisation

- The ontology models were not produced consistently
  - OWL allows variations in definition
- The models were not strong enough
  - Model features caused high reasoning overhead
- No refinement cycle
  - But this would not have addressed all of the issues
- A meta-meta model design process was required
- ISO 15926?

Compositional Models

- Train Configuration
Further Work

- GPS Mappings
- Probabilistic reasoning
- Extending non reasoning off the shelf services for condition monitoring
- Intelligent railway infrastructure

Thank-you.

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