A hybrid model-driven approach for development and testing of an ETCS component

Anno Accademico 2014/2015

relatore
Ch.mo Prof. Dr. Stefano Russo

correlatori
Ch.mo Ing. Baseliyos Jacob DB Netz (D)
Ch.mo Ing. Fabio Scippacercola

candidato
Valerio D’Angelo
Matr. M63/156
Part of this thesis is the result of six months internship research at the Deutsche Bahn AG in Munich, the national railway company of Germany.

The work is involved into the OpenETCS European project:
“A OpenSource approach to provide a development, validation and testing framework of a ETCS System.”
A hybrid model-driven approach for development and testing of an ETCS component

Context

- Complexity and pervasiveness of software in society is growing
  - Standard constraints – High Quality Required – Time to market
- Abstraction as solution to handle the complexity
- The Model-Driven approach: the state of the art of abstraction process

The railway sector is undergoing a transition period from the National Systems to a new European signalling

*Opportunity to explore new approaches and methods*

An important challenge is to find the right development process suitable to the needs of a company
Proposition for a **hybrid model-driven approach** for development and testing in the railway sector:

- **Analysis of documented cases**
  - OMG Based
  - Non standard based

- **Formalization of the hybrid approach**
  - Requirements analysis
    (User stories of OpenETCS process)
  - Development phase
    (OMG Models)
  - Testing phase
    (Model-in-the-loop)
  - Adaptation of the available tools
    (SCADE, Eclipse)
A hybrid model-driven approach for development and testing of an ETCS component

MODEL
- A representation of a system/phenomenon highlighting the essential aspects.
- Supports every phases of the process, from requirements analysis to code generation

Model Driven Architecture
- Standardized by OMG
- Allows developers and user to:
  - Productively design
  - Lower cost of application development and management
  - Enhance interoperability

System is described at different level of details through a set of models and transformation rules

- CIM: Computation Independent Model
- PIM: Platform Independent Model
- PSM: Platform Specific Model
The international trains which cross many States are forced to be equipped with several signalling systems or to stop at the border.

The European Transport minister started in the 1980s to formulate a strategy to develop a single train control system standard to apply across Europe.

ETCS provides 5 levels of supervision:

- **Level STM** National Train Control
- **Level 0** Train is ETCS-fitted, Track not jet.
- **Level 1** Intermittent track-to-train communication (Eurobalises and Euroloop)
- **Level 2** Continuous track-to-train communication (RBC Radio Block Centre)
- **Level 3** Similarly to Level 2, still under evaluation.
A hybrid model-driven approach for development and testing of an ETCS component

The On Board Unit (OBU) includes all devices placed inside the train Cab.

The track-side equipment includes all devices placed on the track (intermittent and continuous communication devices)

**TIU:** Train Interface Unit is the interface to control - command: engine, position checks, emergency brake.

**Balise:** Electronic device or transponder placed between rails. (Intermittent communication)

**Loop:** Coaxial cable with a resistor placed along the rails. (semi-continuous communication)

**DMI:** Driver Machine Interface It’s the main means of interaction between driver and train.

**EVC:** European Vital Computer core component of OBU. It processes the trainborne functions.

**RBC:** Radio Block Centre send/receive message through radio frequency. (continuous communication)
**A hybrid model-driven approach for development and testing of an ETCS component**

### Documented Cases

#### OMG-based approach

**Model-Driven Engineering of a Railway Interlocking System**

- Strategy to support the verification and validation activities
- V-Model development and testing approach
- CIM, PIM, PSM and CIT models used
- UML, UTP profile used
- Rational Rhapsody, Conformique

![OMG-based approach diagram](image)

#### Non OMG-based approach

**OpenETCS process**

- Strategy to create a framework to support development, validation and verification activities
- Waterfall-like approach
- User Stories specification
- SysML, UML, SCADE language
- SCADE, Eclipse

![Non OMG-based approach diagram](image)
Hybrid model-driven approach: hot points

In accordance with OpenETCS process real use case scenarios (*User Stories*) are used as early as possible in the development process.

- The typical MDA models at different level of abstraction (CIM PIM and CIT)
- SysML and SCADE as modelling language
- Model-in-the-Loop technique as testing strategy
- Automatic C-Code generation
- Test scripts and Model Coverage report
A hybrid model-driven approach for development and testing of an ETCS component

Case Study 1/3

**ETCS Driver Machine Interface:** display of the On Board Unit, the principal means the Driver uses to interact with the Train

- **Touchscreen** and **Softscreen** technology
- **Ergonomic** principles from European standard
- Provides Track Description, Speed Monitoring and Status Informations
- Allows *Driver Data, Train Data* and *Track Data* entry/validation
- SIL-2 Compliant
A hybrid model-driven approach for development and testing of an ETCS component

Case Study 2/3

CIM describes a simplified version of OBU
- Only the involved OBU blocks are considered
- Architecture and Data flow in SysML (BDD and IBD)

DMI Manager: adapter between DMI and EVC

DMI Display: Graphical widgets
DMI Controller: Behavioural logic

DMI consists of DMI Display and DMI Controller

Data flow of the On Board Unit
A hybrid model-driven approach for development and testing of an ETCS component

Case Study 3/3

Architecture of DMI Controller

- **Initialization Mng**: Initialization of values, handshake with EVC
- **Incon Mng**: displays and checks of ETCS symbols
- **Menu Mng**: displays and checks of menus
- **Messages Mng**: Displays text messages (Acknowledgment check if required)
- **Periodic Info Mng**: Performs Speed Pointer and Circular Speed Gauge colour and movement
- **Train Data**: Displays and storages of Train Data
- **Planning Data**: Displays track-side information (Gradient profile, Static Speed Profile etc.)
A hybrid model-driven approach for development and testing of an ETCS component

Model in the Loop testing 1/2

- CIT and PIM are both executable
- CIT and PIM have a complementary interface
- CIT is organized in test scenarios traceable with requirements
- SCADE modelling language is used
A hybrid model-driven approach for development and testing of an ETCS component

Model in the Loop testing 2/2

Select scenario
- Start of Mission
- Entry Driver ID and Train ID
- Validation ETCS Level
- Acknowledgement of SN Mode
- Transition and Acknowledgement of ETCS Level transition
- Speed Monitoring

Test results

Model Coverage Report
- Green: Fully covered
- Yellow: Partially covered
- Red: Not covered
Conclusions

Suggested an hybrid development and testing approach for the railway sector.
- MDA models, V-Model
- Automatic C-Code generation
- Model-in-the-Loop testing
- Model Coverage report

Future Work
- Better automation of test cases
- White Box Testing