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Eureka Σ I 3674 Programme, ITEA2 project ip06035
 SINTEF / Andreas Svendsen, 2011-05-03

Train Control Language (TCL)

Andreas Svendsen (SINTEF & UiO)

Work performed in collaboration with ABB

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Metamodeling

Metamodel (Language)

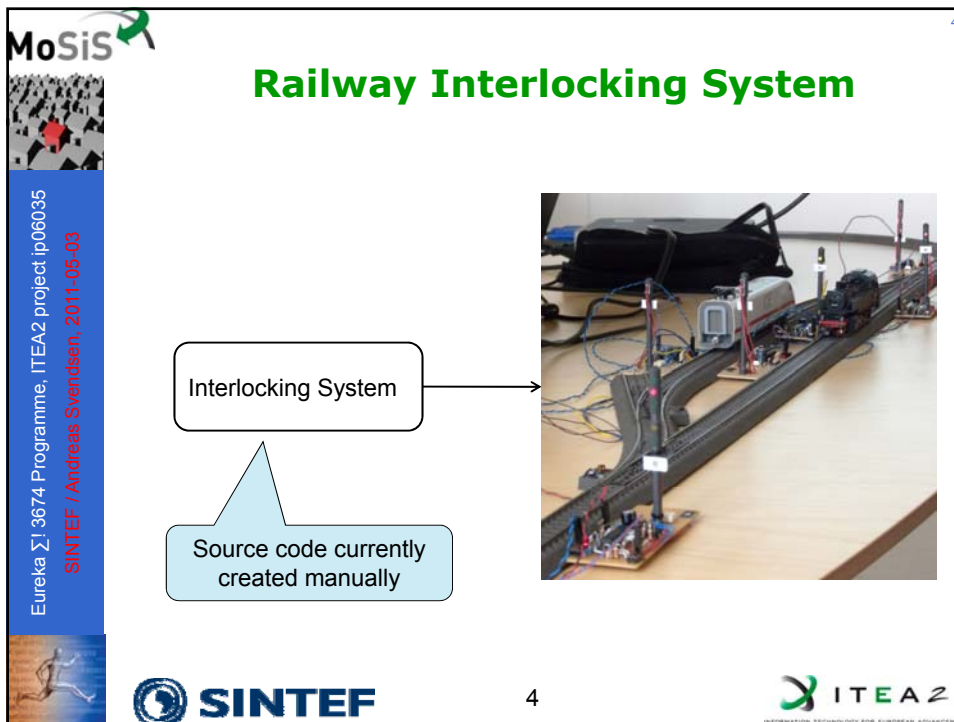
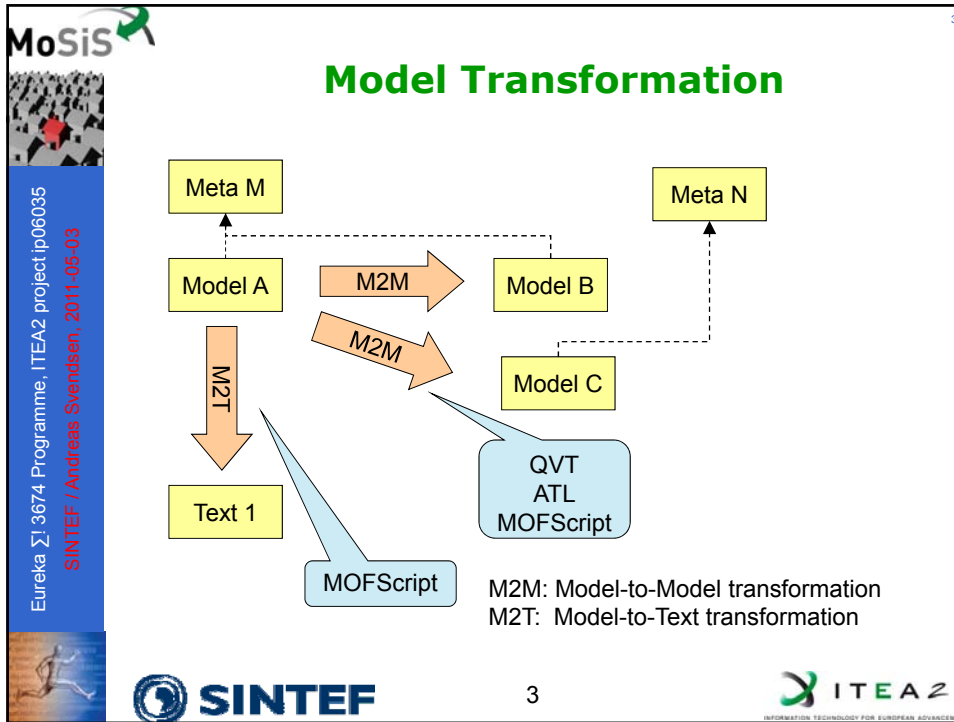
Instance of metamodel (Model)

Abstract Syntax

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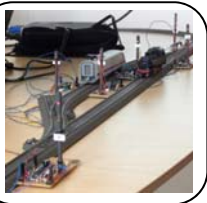
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Domain Specific Language

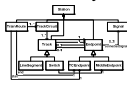
Domain



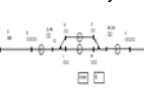
DSL

Definitions

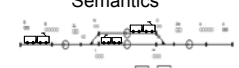
Abstract syntax



Concrete syntax



Semantics




Generated code


```
Str_br_1(
  Hj_Str_br:=Felles.Hj_Str_br,
  Sf_n1_F := Sf_A.Fk,
  Sf_n2_F := Sf_B.Fk,
  TP := TID.tStr_br,
  Str_br => Felles.Str_br
);
```



Tools

Editors



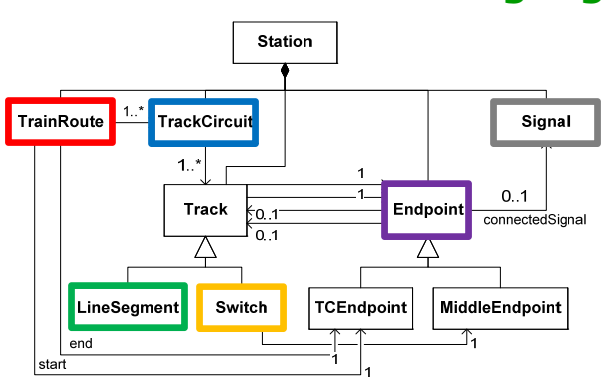
Code generators

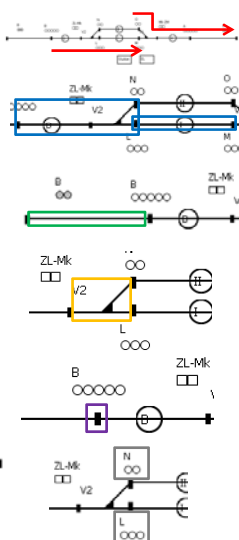





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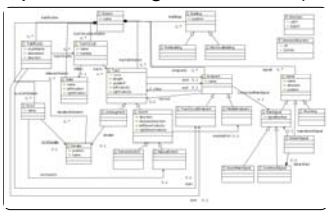



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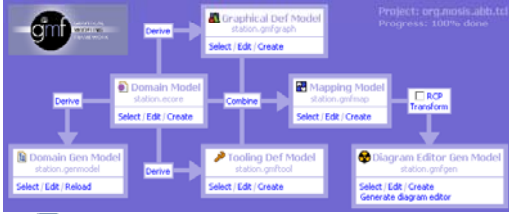
Eclipse Based Tools

Eclipse Modeling Framework (EMF)



↓

Graphical Modeling Framework (GMF)



MOFScript


```


* Returns a list of all TCs that have to be occupied for this TR.
* filter - filter out special TCs (L and I)
*/
module: getOccupiedTCs(tr:station.TrainRoute, filter:Boolean) : List{
  var res:List
  tr.trackCircuits->forEach(tc:station.TrackCircuit){
    if ((!filter) or (filter and tc.stillers != null)){
      res.add(tc)
    }
  }
  if (!isDeparture(tr)) { //are we entering the station?
    //since the station does not support two trains entering
    //simultaneously, we need to reserve an extra TC
    var tc:station.TrackCircuit = getNextTC(tr)
    if ((!filter) or (filter and tc.stillers != null)){
      res.add(tc)
    }
  }
  return res
}

```

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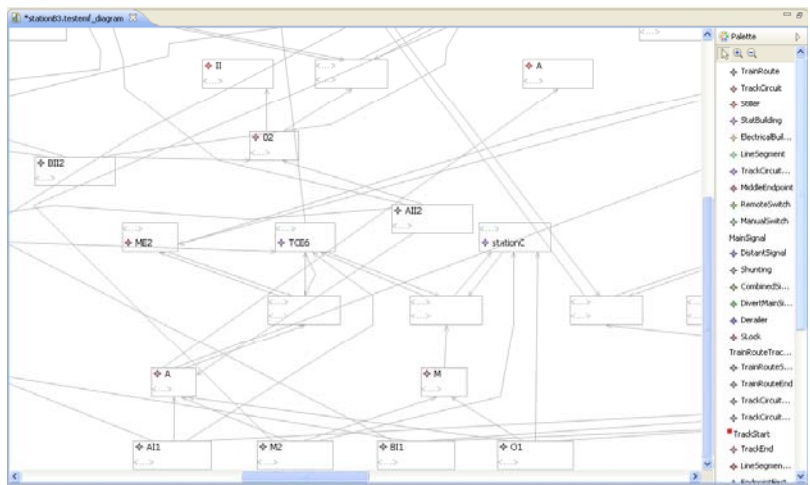
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Initial GMF Editor



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TCL Editor

Code generation

Station model

Property view

Tool palette

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TCL Transformation

Str_br_1(
Hj_Str_br:=Felles.Hj_Str_br,
Sf_n1_F := Sf_A.Fk,
Sf_n2_F := Sf_B.Fk,
TP := TID.tStr_br,
Str_br => Felles.Str_br
);

Train Route Description	Train Route	Staller B	Staller A	Staller II	Staller I	Switch V2	Switch V1	Train Routes			Track Circuits						
		L N	B A	A N	B A			B I	L 1	M 2	O 1	A I	A I	L B	O 1	O 2	A M
From StationA to Track 1	BI2	-	-	-	-	-	+	-	+	+	+	+	+	+	+	+	+
From StationA to Track 2	BI1	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+
From Track 1 to StationA	L2	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
From Track 2 to StationA	N1	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+
From Track 1 to StationC	M2	-	-	-	-	-	+	-	+	+	+	+	+	+	+	+	+
From Track 2 to StationC	O1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
From StationC to Track 1	AI2	-	-	-	-	-	+	-	+	+	+	+	+	+	+	+	+
From StationC to Track 2	AI1	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+

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TCL Models

StationB

StationD

StationM

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Analysis of TCL Models

Functional Specification:
 $x = (Tsp.R/FIK.SIG.254) * (((1^*) * BEL.Sf.B) + U.Tsp.R/FIK.SIG.254) * Str.br$
 $U.Tsp.R/FIK.SIG.254 = Tu(x, t(U.Tsp.R/FIK.SIG.254))$

Function Blocks:
 $Str.br_1(Hj.Str.br = Felles.Hj.Str.br,$
 $Sf.n1.F := Sf.A.Fk,$
 $Sf.n2.F := Sf.B.Fk,$
 $TP := TID, Str.br,$
 $Str.br => Felles.Str.br);$

Testing Phase

Automatic Analysis

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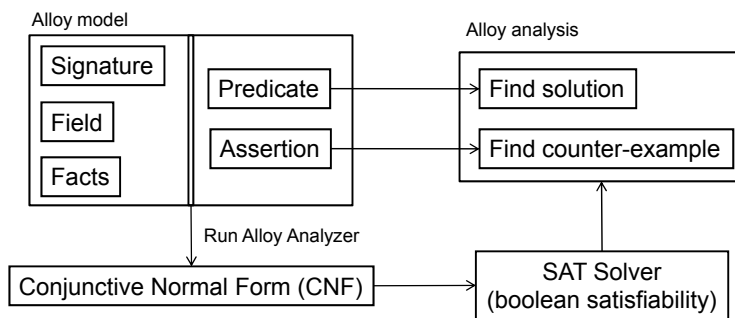
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Alloy

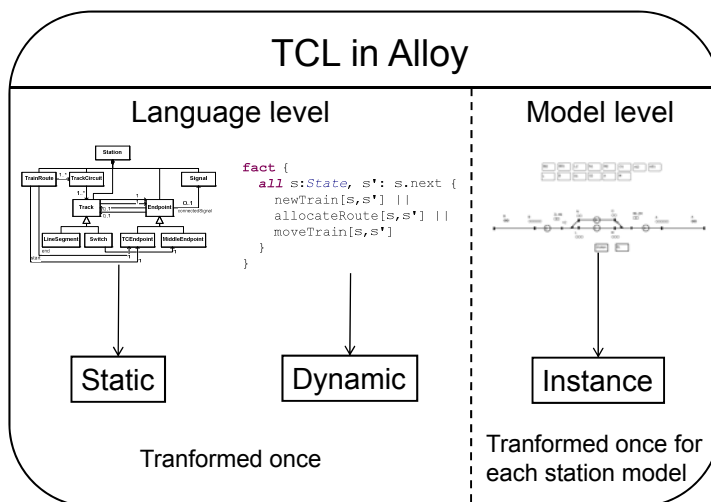
• Structural modeling language

- Based on first-order logic
- Expressing complex structural constraints and behaviours



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Formalizing TCL



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Analysis of TCL Models

- **Constrain the first and last state**
 - Run simulation
 - Assert certain properties

Allocate train route containing occupied track

Find maximum number of trains allowed simultaneously

Station EL

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Performing Analysis

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Performing Analysis (2)

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statiocT_station_diagram

Train movement is highlighted in the editor

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Synthesis of TCL Models

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User-defined properties

TCL Metamodel

TCL Model

Alloy Model

```

abstract sig TrainRoute extends Element {
  trackcircuits: some TrackCircuit,
  start: one TrackCircuitEndpoint,
  end: one TrackCircuitEndpoint,
  direction: one Direction
} (one at:station | this in st.trainRoutes)

//trainroutes have to refer different endpoints
fact {no t:TrainRoute *t.start, e2:t.end | e = e2}

```

Alloy Instance Model

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Generated Station (first attempt)

TR_1_0 TR_2_0 TR_3_0 TR_4_0 TR_5_0 TR_6_0 TR_7_0 TR_8_0
 TC_1_0 TC_2_0 TC_3_0 TC_4_0 TC_5_0 TC_6_0

The diagram shows a station layout with two main tracks, SW_2_0 and SW_1_0, connected by a switch SW_2_0. A signal box 'Station' and an 'EL' (electrical) box are located between the tracks. Three signal posts (ST) are positioned along the tracks. To the right, various signal types are listed: MSIG_2_0 (OOO), MSIG_1_0 (OOO), DMSIG_1_0 (OO), DMSIG_2_0 (OO), CSIG_1_0 (OOOOO), and CSIG_2_0 (OOOOO).

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Tracks and Signals Are Connected

TR_1_0 TR_2_0 TR_3_0 TR_4_0 TR_5_0 TR_6_0 TR_7_0 TR_8_0
 TC_1_0 TC_2_0 TC_3_0 TC_4_0 TC_5_0 TC_6_0

This diagram shows a more complex station layout with tracks SW_2_0 and SW_1_0. It includes a signal box 'Station' and an 'EL' box. Signal posts (ST) are placed at various points along the tracks. The signal types listed are CSIG_1_0 (OOOOO), MSIG_1_0 (OOO), MSIG_2_0 (OOO), DMSIG_2_0 (OO), CSIG_2_0 (OOOOO), and DMSIG_1_0 (OO).

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Finally

B -> M	M -> R	A -> L	L -> LE	B -> O	O -> R	A -> N	N -> LE	B -> S	S -> R	A -> P	P -> LE
--------	--------	--------	---------	--------	--------	--------	---------	--------	--------	--------	---------

L	M	B	A	011	021	031
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Summary

- **DSL for modeling train stations**
 - Graphical editor
 - Code generators
 - Automatic analysis
 - Early development process
 - No knowledge about formal methods or mathematical notation needed
 - Complementary to traditional validation, verification and testing processes
 - Automatic synthesis of models
- **Challenges**
 - Designing languages
 - Creating code generators

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