Towards one Model Interpreter for Both Design and Deployment

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Overview

1. A New Approach for Design and Deployment of UML Models
   - Context
   - Issues
   - Approach
   - Case Study
   - Results

2. Design of the Bare-Metal UML Interpreter
   - Interpreter Design
   - Communication Interface

Context

New generation of embedded systems and CPS

- Emergence of new needs
- Connected devices and collaboration on networks (IoT)

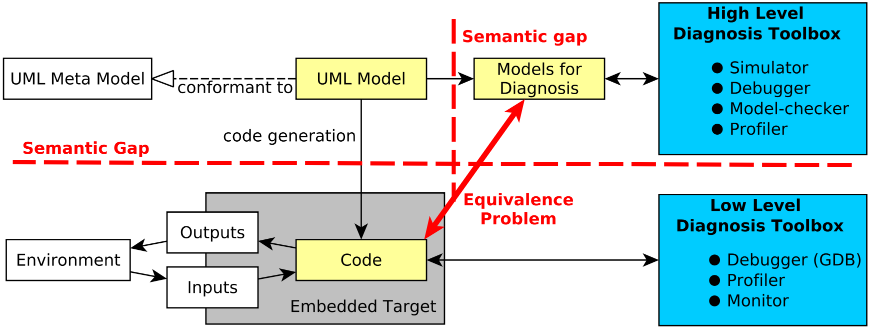
Consequences

- Behavior of systems more uncertain
- Systems more vulnerable to cyber attacks

Needs

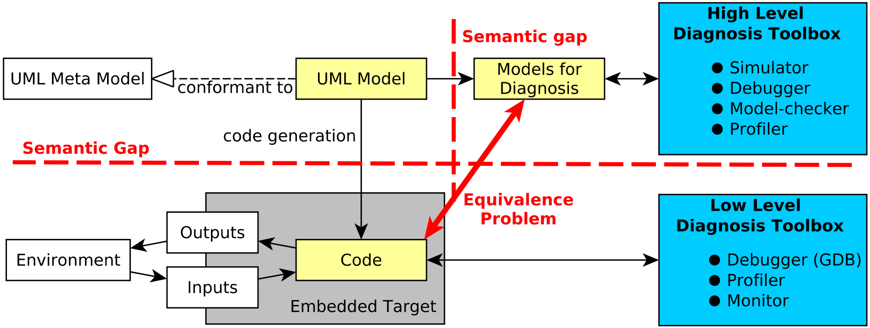
- Simulate, execute, and verify models at early design stage
- Prevent introduction of bugs

Classical Approach and its Issues



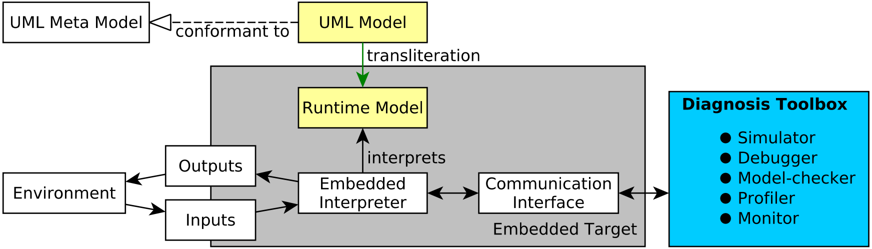
- **Semantic gap**: code and diagnosis results difficult to link to the user model (UML Model)
- **Equivalence**: multiple separate definitions of the semantics language not proven equivalent
- **Diagnosis understandability**: results not expressed over UML or code

Classical Approach and its Issues



Root cause of these problems (semantic gap, equivalence, and diagnosis understandability): multiple implementations of UML semantics by transformations towards different formalisms

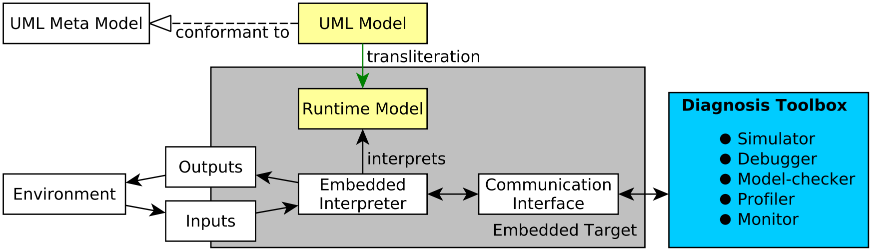
Our Approach



Key points

- Use of a **single semantics implementation** centralized in a UML model interpreter
  - Avoid multiple implementations of the language semantics by transformations for which we do not know how to prove their equivalence

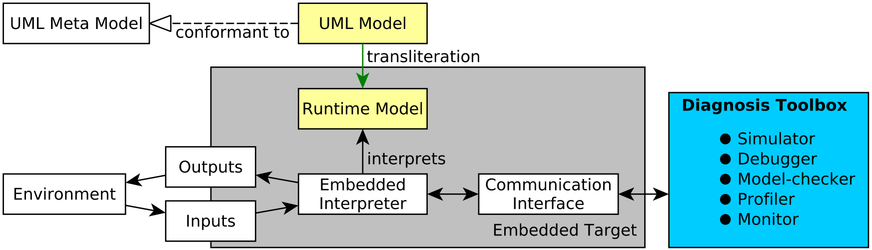
Our Approach



Solutions

- Semantic gap and equivalence issues: avoided by having only one model
- Diagnosis understandability issue: results directly linked to the UML model

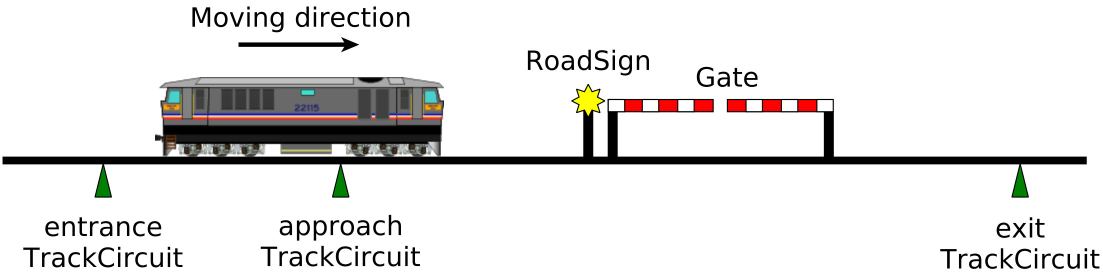
Our Approach



A new issue

A **lack of diagnosis tools** for this approach that we addressed with an execution control interface (similar to a debugger interface).

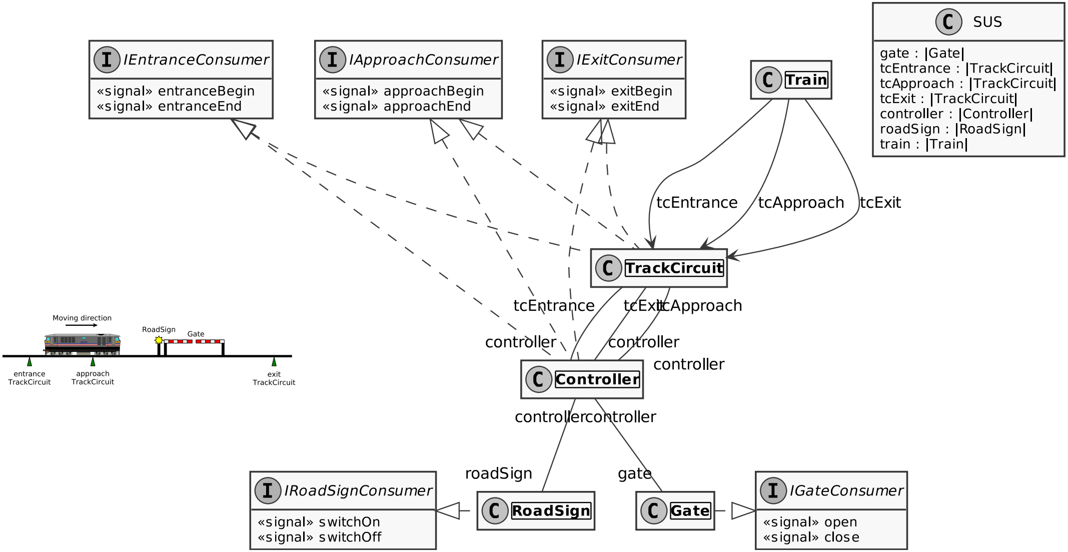
Case Study: Level Crossing



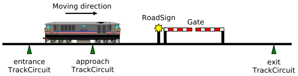
Goal

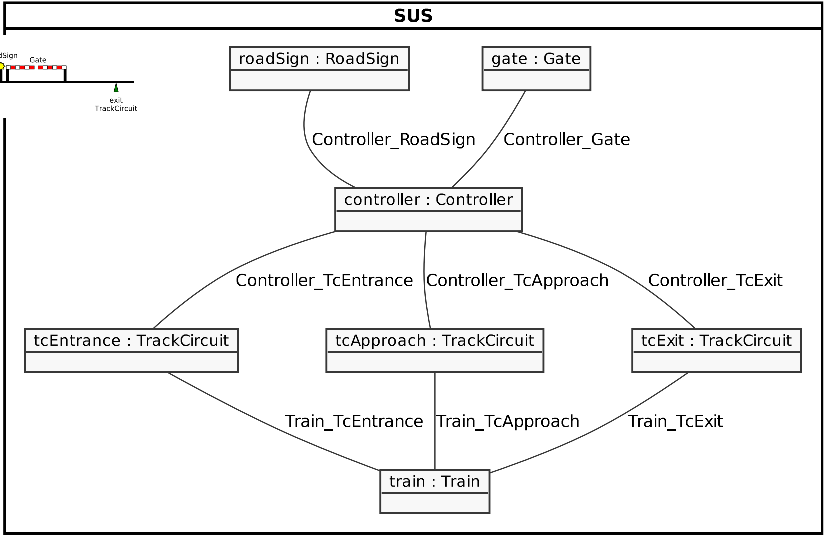
Ensure the safety of all road users during the passage of the train at the intersection of the railroad with the road

Case Study: Level Crossing (Class Diagram)

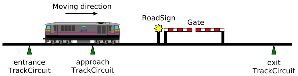


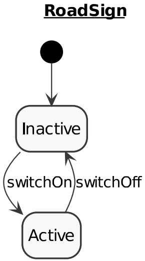
Case Study: Level Crossing (Composite Structure Diagram)

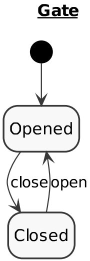


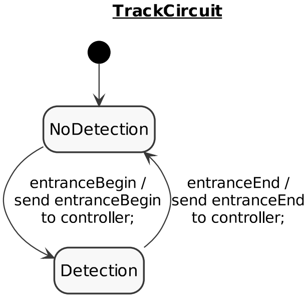


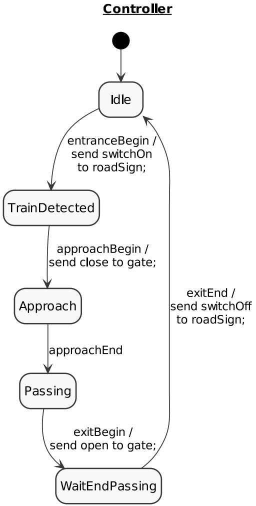
Case Study: Level Crossing (State Machines)







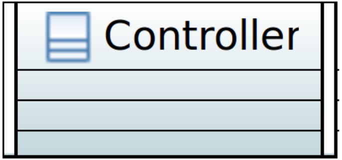




Deployment

Deployment process

- Design of the level crossing model in Eclipse UML (graphically with Papyrus or textually with tUML)




```
class |Controller| behavesAs SM {
  stateMachine SM {}
}
```

Deployment

Deployment process

- Design of the level crossing model in Eclipse UML (graphically with Papyrus or textually with tUML)

```
<packagedElement xmi:type="uml:Class"
  xmi:id="_hcP2cJFrEeeKv5ZjdgN-yQ"name="Controller"
  classifierBehavior="_hcXyQJFrEeeKv5ZjdgN-yQ" isActive="true">
  <ownedBehavior xmi:type="uml:StateMachine"
    xmi:id="_hcXyQJFrEeeKv5ZjdgN-yQ" name="SM">
  </ownedBehavior>
</packagedElement>
```

Deployment

Deployment process

- Design of the level crossing model in Eclipse UML (graphically with Papyrus or textually with tUML)
- Transliteration into C language as struct initializers

```
UML_Class class__Controller = {
  .c_kind = C_UML_Class,
  .visibility = UML_PUBLIC,
  .name = "Controller",
  .classifierBehavior = (UML_Behavior*)&stateMachine__Controller,
  .isActive = 1
};
```

Deployment

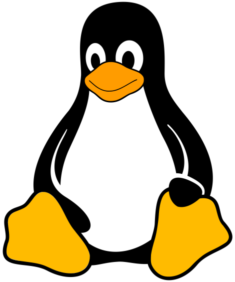
Deployment process

- Design of the level crossing model in Eclipse UML (graphically with Papyrus or textually with tUML)
- Transliteration into C language as struct initializers
- Model linked at build time with the interpreter

Deployment

Targets

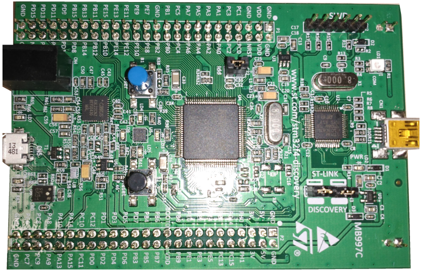
- PC with a Linux operating system + TCP

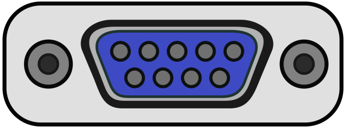


Deployment

Targets

- PC with a Linux operating system + TCP
- stm32 on bare-metal + RS232

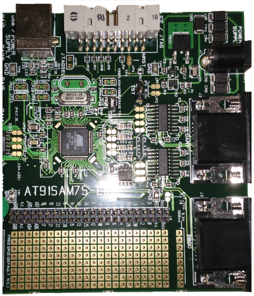




Deployment

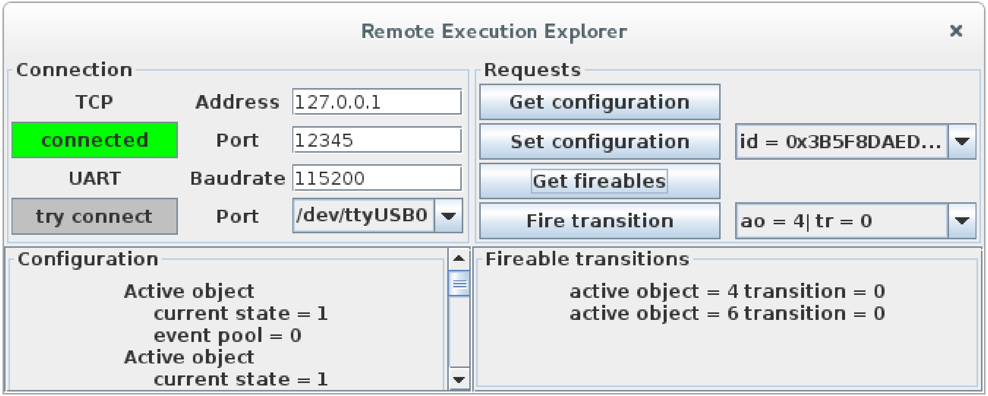
Targets

- PC with a Linux operating system + TCP
- stm32 on bare-metal + RS232
- at91sam7s on bare-metal (microcontroller used by Lego NXT) + RS232 (target used only for simulation)



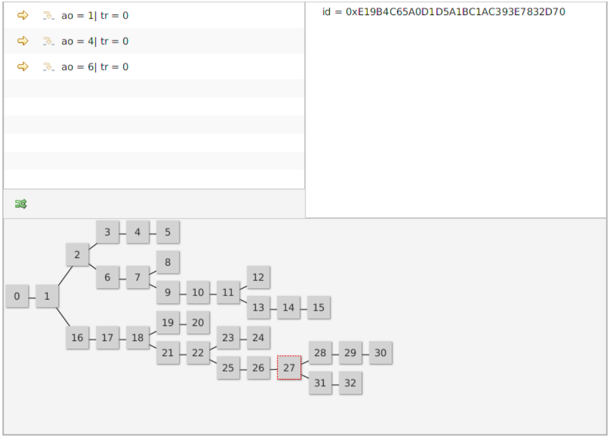
Simulation

- Connection possible over TCP or RS232 (via UART peripheral)
- Four buttons for the four requests of the communication interface
- Step by step or back-in-time execution available



Simulation

- History: all states encountered are stored
- Back-in-time execution: possibility to reload a previous state of the model



State-space exploration

- Use of a breadth first search algorithm
- Level crossing model: 1,825 configurations and 5,793 transitions

Interpreter Design

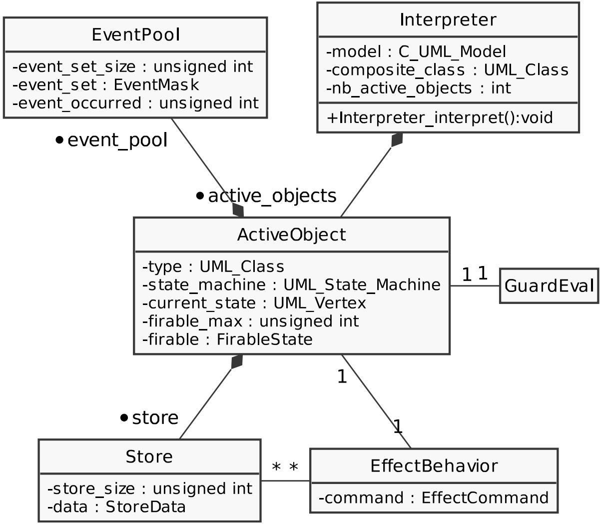
Three components

- metamodel: definition of the language semantics
- model: representation of the static part of the system
- interpreter: representation of the dynamic part of the system and execution support

Key points

- An interpreter deployable as OS task or process (e.g., Linux) or bare-metal (without OS)
- Each instance of active classes represented as an active object
- Each active object has:
  - An event pool to receive events
  - A current state
  - A store for its attributes

Interpreter Design



Interpreter Design

Semantics definition tUML

A subset of Eclipse UML including:

- class diagram
- state machines diagram
- composite structure diagram

Effects and guards

Implemented as OpaqueBehaviors and OpaqueExpressions in a language that enables to:

- send events
- assign values to attributes

Communication Interface

Goal

Solve the lack of specific diagnosis tools by providing a generic API to control remotely the execution of the interpreter

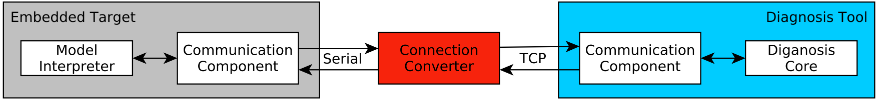
Four requests

- **Get configuration**: collects the current configuration (memory state) of the interpreter.
- **Set configuration**: loads a configuration as the current memory state of the interpreter.
- **Get fireable transitions**: gets transitions that have their trigger and their guard satisfied in the current state.
- **Fire a transition**: fires a fireable transition of an *ActiveObject*.

Communication Interface

Possibility to connect existing tools

- No needs to implement an ad-hoc toolbox
- Existing tools used and approved for several years
- No formation required for engineers



How to connect a diagnosis tool ?

- Implement a TCP client and requests of the communication interface
- Use the connection converter to make the conversion into serial frames

Conclusion

Our contribution

- Use of a single semantics definition to overcome the semantic gap and the equivalence problem between models
- Implementation of a bare-metal UML interpreter
- Definition of a communication interface to enable the use of existing tools and fix the lack of diagnosis toolboxes specific to our interpreter
- Remote control of the model execution with both a simulator and a state-space explorer

Perspectives

- Implementation of formal properties verification
- Connection of this interpreter with a model-checker
- Application of this approach to other languages (e.g., DSLs)