Implementation of an Interpreter for the Test Purpose Specification Language TDL^{TP}

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Presentation Outline

1. Context
2. Objective
3. Implementation
4. Validation
5. Summary

Next Section

1. Context
    - Model-Based Testing
    - UPPAAL
    - Test Purpose Specification Language TDL$^{\mathrm{TP}}$
2. Objective
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Context – Model-Based Testing

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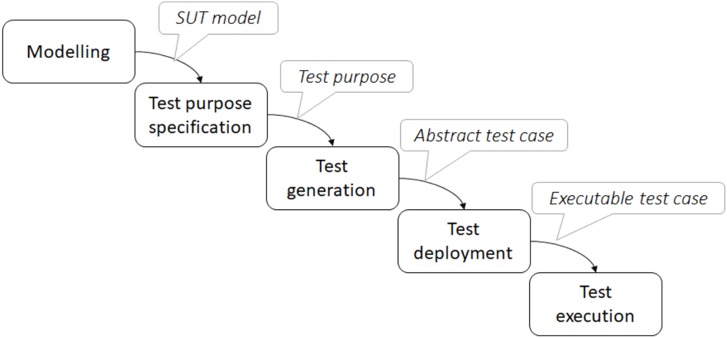

Figure 1. Potential MBT workflow.

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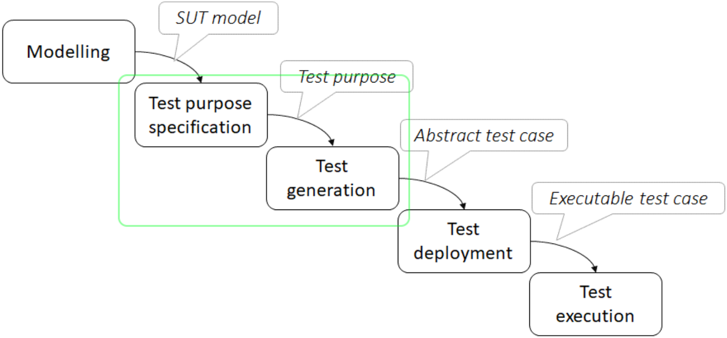

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Context – Model-Based Testing (cont'd)

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Derivation of abstract test sequences from the state space of a SUT model using test purposes as guiding constraints.

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- reduce costs.

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- graphical environment for defining UTA models,
- simulator which allows user to execute a model and observe its behavior,
- model-checker (`verifyta`) – provides tools for the formal verification of correctness properties for the model (and the generation of *witness traces* which prove these properties).

Context – UPPAAL (cont'd)

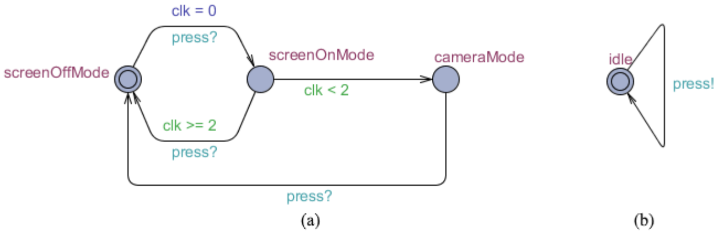

Figure 2. Example UPPAAL automata: (a) smartphone, (b) user.

Context – UPPAAL (cont'd)

UPPAAL's property specification language can be used to express test purposes.

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- state formulae:

  `systemProcess.workCompleted;`

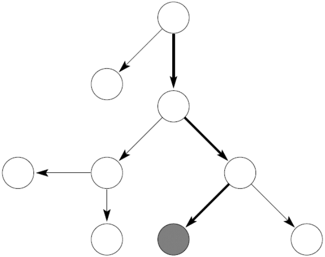


Figure 3. Verification of reachability property `E<>p`.

Context – UPPAAL (cont'd)

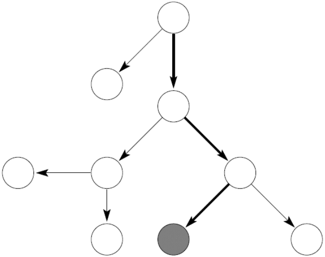
UPPAAL's property specification language can be used to express test purposes.

Formula types:

- state formulae:

  `systemProcess.workCompleted`;
- path formulae:

  `E<>systemProcess.workCompleted`.



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Solution:

Evelin Halling, Jüri Vain, Artem Boyarchuk, and Oleg Illiashenko, **"Test Scenario Specification Language for Model-based Testing"**, *International Journal of Computing*, 2019.

Context – Test Purpose Spec. Language TDL$^{\text{TP}}$ (cont'd)

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- test purposes are encoded as logical expressions, e.g.

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A(TS1) ~> E(TS2) & E(TS3);
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- root automaton in the recognizer tree (`stopwatch`) is intended to be used in the UPPAAL reachability query `E<>stopwatch.pass`;
- witness trace generated per query is an abstract test case.

Context – Test Purpose Spec. Language TDL^{TP} (cont'd)

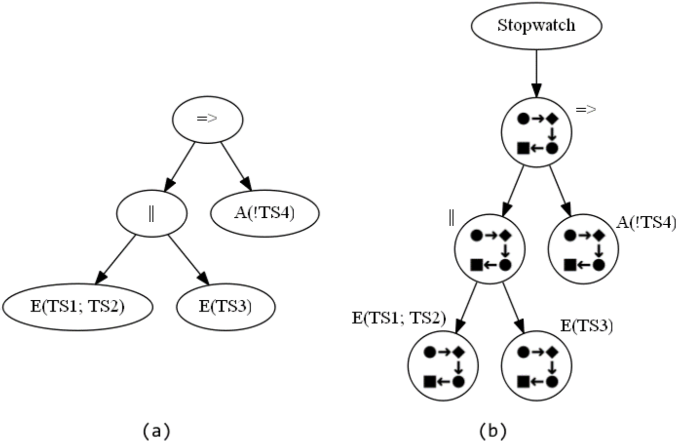
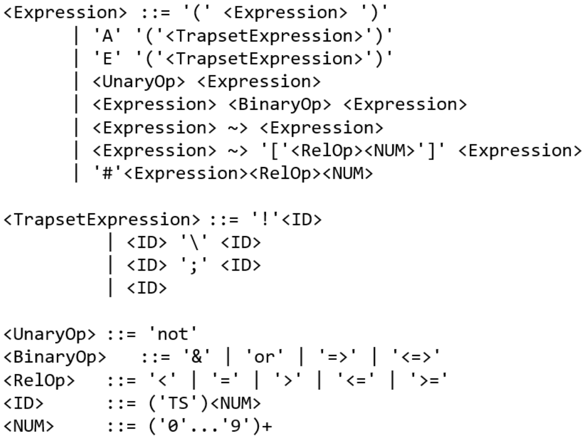


Figure 4. Comparison of TDL^{TP} AST (a) and corresponding recognizer tree (b).

Context – Test Purpose Spec. Language TDL^{TP} (cont'd)



```
<Expression> ::= '(' <Expression> ')'
       | 'A' '('<TrapsetExpression>')'
       | 'E' '('<TrapsetExpression>')'
       | <UnaryOp> <Expression>
       | <Expression> <BinaryOp> <Expression>
       | <Expression> ~> <Expression>
       | <Expression> ~> '['<RelOp><NUM>']' <Expression>
       | '#'<Expression><RelOp><NUM>

<TrapsetExpression> ::= '!'<ID>
          | <ID> '\' <ID>
          | <ID> ';' <ID>
          | <ID>

<UnaryOp> ::= 'not'
<BinaryOp>   ::= '&' | 'or' | '=>' | '<=>'
<RelOp>   ::= '<' | '=' | '>' | '<=' | '>='
<ID>      ::= ('TS')<NUM>
<NUM>     ::= ('0'...'9')+
```

Figure 5. TDL^{TP} grammar.

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Objective

Goal Statement

Implement an interpreter that accepts as input:

- a $\mathrm{TDL}^{\mathrm{TP}}$ expression,
- a UPPAAL SUT model,

and produces a **test model** as output.

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- efficiency is not an immediate concern;

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Caveats:

- efficiency is not an immediate concern;
- assume model validity wrt system requirements.

Objective (cont'd)

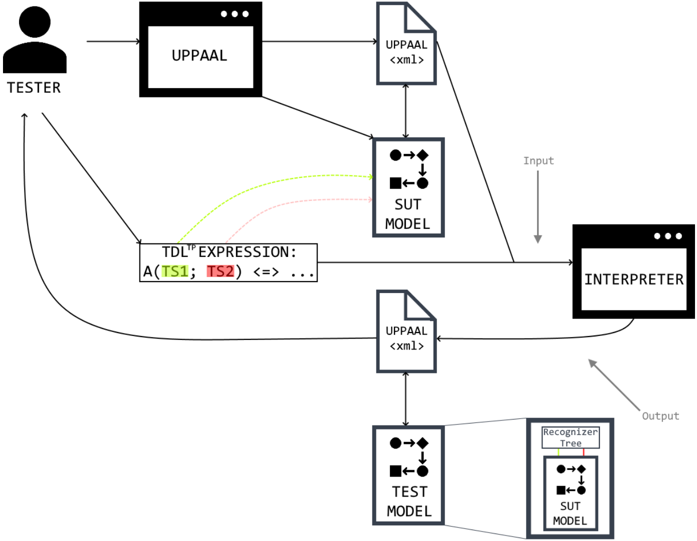

Figure 6. Interaction diagram.

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   - Approach
   - Structure
   - Demonstration
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Implementation – Approach

Takes inspiration from Component-Based Development (CBD).

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General process:

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General process:

- identify necessary sub-functionalities;
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Benefits:

- limit coupling;
- enforce reusability;
- facilitate refactoring.

Implementation – Structure

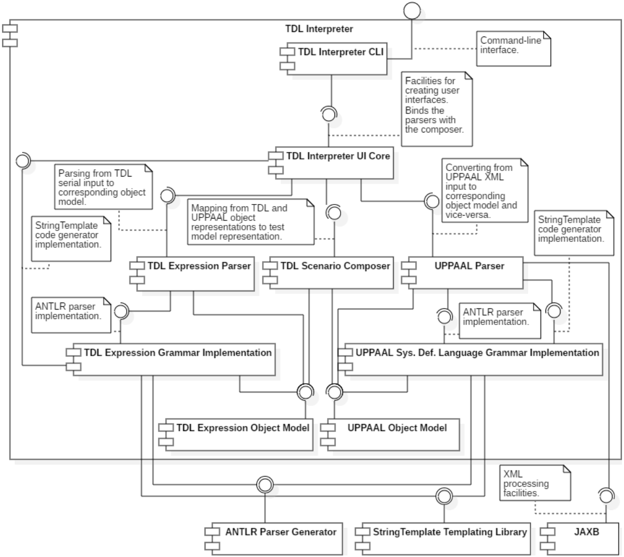
TDL Interpreter
TDL Interpreter CLI
Command-line interface.
Facilities for creating user interfaces. Binds the parsers with the composer.
TDL Interpreter UI Core
Parsing from TDL serial input to corresponding object model.
Converting from UPPAAL XML input to corresponding object model and vice-versa.
Mapping from TDL and UPPAAL object representations to test model representation.
StringTemplate code generator implementation.
StringTemplate code generator implementation.
TDL Expression Parser
TDL Scenario Composer
UPPAAL Parser
ANTLR parser implementation.
ANTLR parser implementation.
TDL Expression Grammar Implementation
UPPAAL Sys. Def. Language Grammar Implementation
TDL Expression Object Model
UPPAAL Object Model
XML processing facilities.
ANTLR Parser Generator
StringTemplate Templating Library
JAXB

Figure 7. Partial component diagram.

Demonstration

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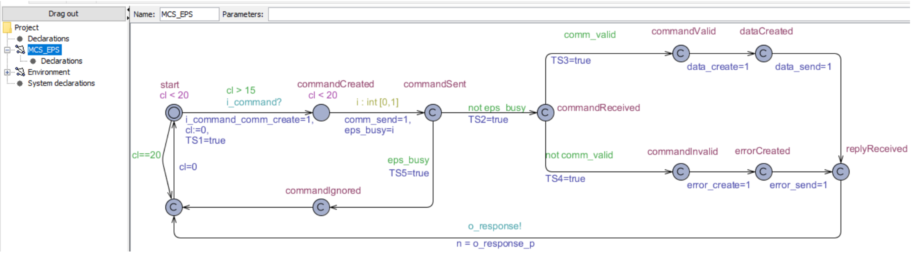

Name: MCS_EPS

Parameters:

Figure 8. Example UPPAAL input model.

Demonstration

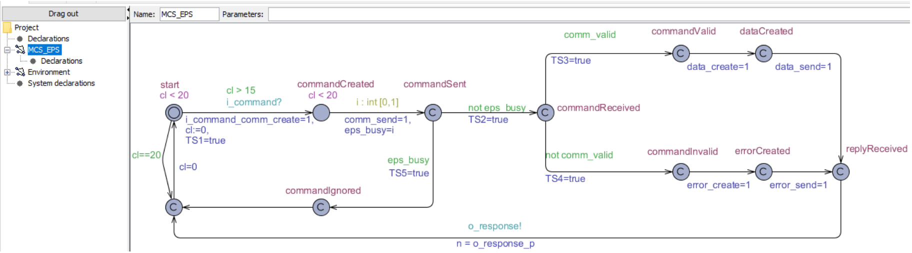

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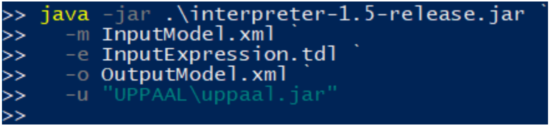
Figure 8. Example UPPAAL input model.

```
A(TS2;TS4) ~> E(TS2;TS3)
```

Figure 9. Example TDL^{TP} input expression.

Demonstration (cont'd)



```
>> java -jar .\interpreter-1.5-release.jar `
>>    -m InputModel.xml `
>>    -e InputExpression.tdl `
>>    -o OutputModel.xml `
>>    -u "UPPAAL\uppaal.jar"
>>
```

Figure 10. Call to interpreter command-line interface.

Demonstration (cont'd)

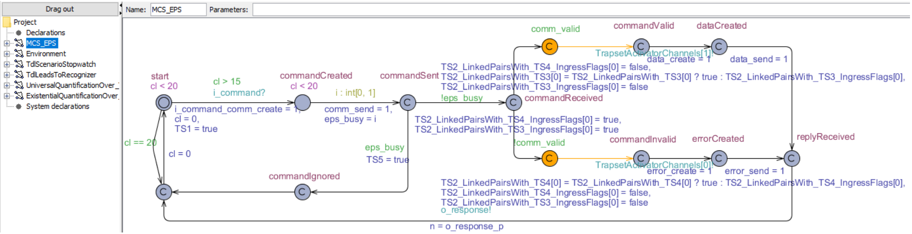

Drag out
Project
Declarations
MCS_EPS
Environment
TdlScenarioStopwatch
TdlLeadsToRecognizer
UniversalQuantificationOver_
ExistentialQuantificationOver_
System declarations
Name: MCS_EPS
Parameters:
start
cl < 20
cl > 15
i_command?
i_command_comm_create = 1,
cl = 0,
TS1 = true
commandCreated
cl < 20
i : int[0, 1]
comm_send = 1,
eps_busy = i
commandSent
!eps_busy
eps_busy
TS5 = true
cl == 20
cl = 0
commandIgnored
commandReceived
TS2_LinkedPairsWith_TS4_IngressFlags[0] = false,
TS2_LinkedPairsWith_TS3[0] = TS2_LinkedPairsWith_TS3[0] ? true : TS2_LinkedPairsWith_TS3_IngressFlags[0],
TS2_LinkedPairsWith_TS3_IngressFlags[0] = false
TS2_LinkedPairsWith_TS4_IngressFlags[0] = true,
TS2_LinkedPairsWith_TS3_IngressFlags[0] = true
comm_valid
commandValid
dataCreated
TrapsetActivatorChannels[1]!
data_create = 1
data_send = 1
!comm_valid
commandInvalid
errorCreated
replyReceived
TrapsetActivatorChannels[0]!
error_create = 1
error_send = 1
TS2_LinkedPairsWith_TS4[0] = TS2_LinkedPairsWith_TS4[0] ? true : TS2_LinkedPairsWith_TS4_IngressFlags[0],
TS2_LinkedPairsWith_TS4_IngressFlags[0] = false,
TS2_LinkedPairsWith_TS3_IngressFlags[0] = false
o_response!
n = o_response_p

Figure 11. Example test model.

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- Multiple component interactions are involved in test model generation – need to ensure the output conforms to rules of TDL^{TP}.
- Rules are well-defined, so automated validation is feasible (but complicated).
- Due to time limitations, most validation efforts were manual.
- User input processing partially covered by automated tests.

Validation (cont'd)

Automated tests for language parsers:

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- 109 automated test cases – handful of programming defects discovered and resolved.

Validation (cont'd)

Automated tests for language parsers:

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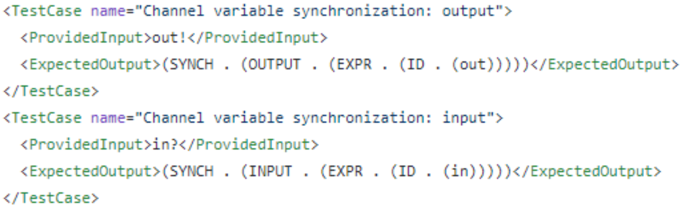

```
<TestCase name="Channel variable synchronization: output">
  <ProvidedInput>out!</ProvidedInput>
  <ExpectedOutput>(SYNCH . (OUTPUT . (EXPR . (ID . (out)))))</ExpectedOutput>
</TestCase>
<TestCase name="Channel variable synchronization: input">
  <ProvidedInput>in?</ProvidedInput>
  <ExpectedOutput>(SYNCH . (INPUT . (EXPR . (ID . (in)))))</ExpectedOutput>
</TestCase>
```

Figure 12. Example automated UPPAAL language parser test cases.

Validation (cont'd)

Manual integration tests:

- *Strategy*: define basic input model, TDL$^{\text{TP}}$ expression.

Validation (cont'd)

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Validation (cont'd)

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- *Strategy*: define basic input model, TDL$^{\mathrm{TP}}$ expression.
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- 95 manual test cases – 4 logical errors, 1 user-friendliness issue, handful of code defects discovered and resolved.

Validation (cont’d)

Manual integration tests:

- *Strategy*: define basic input model, TDL^{TP} expression.
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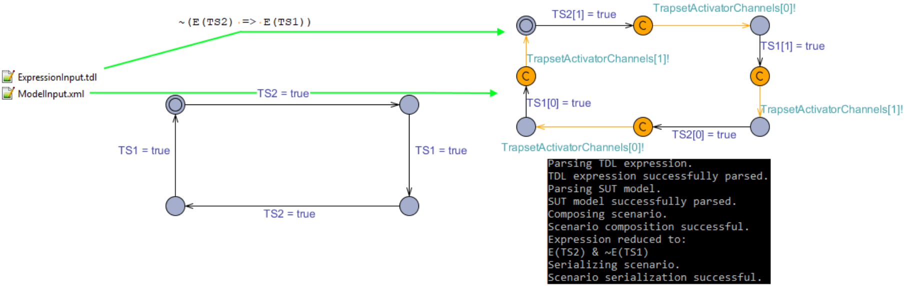

```
Parsing TDL expression.
TDL expression successfully parsed.
Parsing SUT model.
SUT model successfully parsed.
Composing scenario.
Scenario composition successful.
Expression reduced to:
E(TS2) & ~E(TS1)
Serializing scenario.
Scenario serialization successful.
```

Figure 13. Example integration test case.

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Future work:

- resolve major open questions in TDL^{TP} theory uncovered as part of this work (discussed in Sections 5.3, 5.2.2, Appendices 5 – 6 of the thesis);

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- expand automated test coverage;

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- Project management/code repository: TalTech GitLab.

Future work:

- resolve major open questions in TDL^{TP} theory uncovered as part of this work (discussed in Sections 5.3, 5.2.2, Appendices 5 – 6 of the thesis);
- expand automated test coverage;
- graphical user interface for annotating input model according to the TDL^{TP} input expression;

Summary

In summary:

- *Goal*: implement an interpreter based on the theory of TDL^{TP}.
- *Assessment*: successfully implemented, sufficiently validated.
- The interpreter will find use in a prototype environment for MBT of cyber-physical systems under development at TalTech for several years;
- Project management/code repository: TalTech GitLab.

Future work:

- resolve major open questions in TDL^{TP} theory uncovered as part of this work (discussed in Sections 5.3, 5.2.2, Appendices 5 – 6 of the thesis);
- expand automated test coverage;
- graphical user interface for annotating input model according to the TDL^{TP} input expression;
- codebase: apply generalizations where applicable.

Summary (cont'd)

toggl was used to record time spent on the thesis.

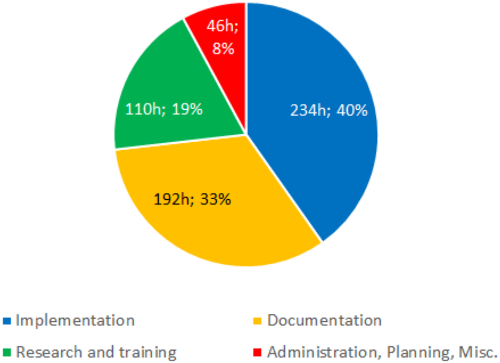

Figure 14. Overview of thesis scope.