SPTG: Symbolic Path-Guided Test Case Generator

Table of content

SPTG overview

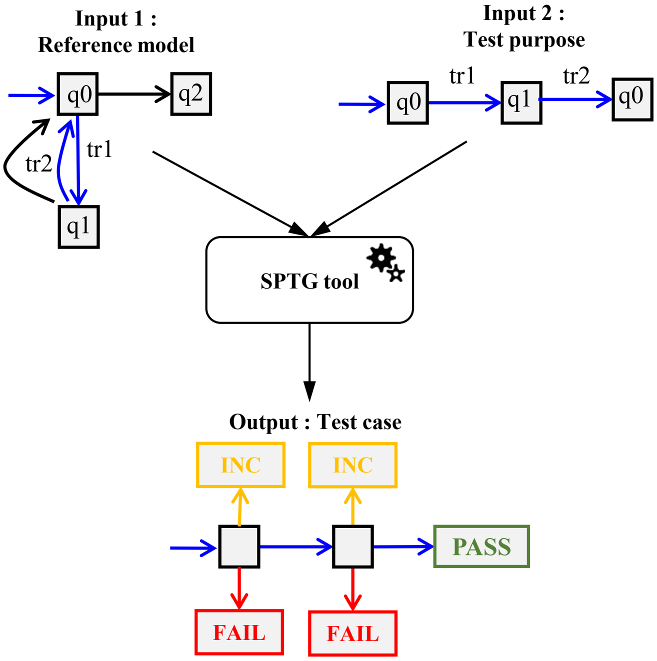


Figure 1: Schematic view of SPTG showing the model automaton with a selected test purpose (blue path) and the generated test case automaton with terminal verdict states.

SPTG is a model-based test generation tool that automatically produces **conformance deterministic test cases** from system models combining both **data** and **timing constraints**. As shown in **Figure 1**, SPTG takes an **automaton model** and a **test purpose**, i.e., a path of the model, and generates the corresponding **test case automaton** with **verdict states** PASS, FAIL, INC (for inconclusive).

It relies on **path-guided symbolic execution**, which explores the input path and builds **symbolic constraints** over inputs and timing. SPTG embeds the **Z3 SMT solver**, which is used to check the **satisfiability of path conditions** along the main test purpose path and its **immediate divergent paths**, as well as to ensure determinism. Infeasible branches, inconsistent with the test purpose, are pruned early during symbolic exploration, avoiding dead paths that correspond to excluded behaviors.

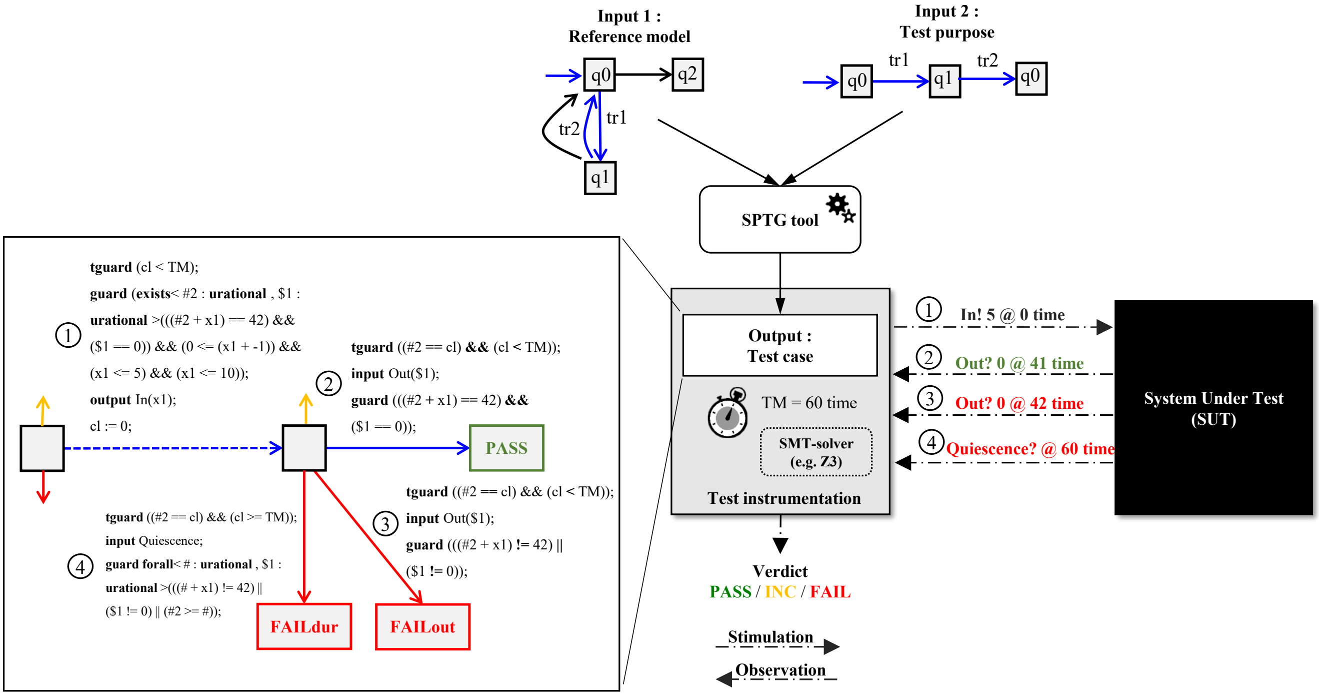


Figure 2: Execution of a generated test case against the System Under Test (SUT) with verdicts determined at runtime.

Figure 2 illustrates the execution phase, where the generated test case interacts with the **System Under Test (SUT)**. During execution, **Z3** is used to solve the **stimulation conditions (guards)**, determining the inputs and timings to apply. Test case transitions are controlled by a clock cl, which satisfies cl < TM, where TM is the maximal waiting time before either applying a stimulation or observing an output. Quiescence, i.e., the obersvation of absence of output, is detected when cl >= TM, indicating that the system remains silent. This timing mechanism, combined with quiescence detection, ensures the test case is implementable in a real-time setting. Additionally, **Z3** checks that the **observed outputs** and their **timings** satisfy the corresponding observation conditions, after which verdicts are assigned.

Applications

- **Model-Based Testing (MBT)** of systems with combined data and timing behaviors.
- **Offline generation** of efficient and deterministic test cases from formal models.
- **Teaching and demonstration** of symbolic execution and model-based test generation principles.

References

SPTG implements the **symbolic path-guided test generation approach**, developed in: 👉 https://doi.org/10.1016/j.scico.2025.103285 *(Open Access)*.

As an extension of the symbolic execution platform Diversity (project details), which is distributed under the Eclipse Formal Modeling Project, SPTG can leverage its coverage analyses for **test purpose selection**, providing an integrated environment for offline timed symbolic testing.

Quick start with SPTG

SPTG directory Structure:

- `bin/`: This directory contains the SPTG tool binary `sptg.exe`. It also includes the PlantUML JAR, which allows visualization and export of generated test cases in graphical PlantUML (SVG) format.
- `examples/`: This directory contains all examples. It has a subdirectory for each example and a script `run-all.sh` to run all preconfigured test case generation tasks. Each example subdirectory includes:
  - The reference model.
  - A preconfigured script `run-sptg.sh` that calls SPTG for test case generation using a test purpose path (a sequence of consecutive transitions of the model). `run-all.sh` calls all `run-sptg.sh` scripts for each example.
- `tutorials/`: This directory contains three tutorials and associated files: tutorial on model specification; tutorial on test case generation; and tutorial on test purpose selection. The latter is a feature that SPTG inherits from extending the symbolic execution platform Diversity.
- `src/`: Contains the C++ source code of SPTG.
- `third-party/`: Directory for third-party libraries and dependencies.
- `Release/`: Contains release artifacts.
- `LICENSE`: The artifact license (same license as the Diversity symbolic execution platform).
- `examples-outputs.zip`: Compressed folder containing outputs generated by executing all examples from our experiments.
- `README`: This file.

First example

```
cd PATH_TO_SPTG/examples/example02_dummy/
run-sptg.sh
```

This script instructs **SPTG** to generate a **test case** with the following specifications:

- **Reference model:** `PATH_TO_SPTG/examples/example02_dummy/example02_dummy.xlia`
- **Test purpose:** Defined as the **sequence of transitions**: `tr1; tr2`
- **Action:** Generate a **test case** corresponding to the given reference model and test purpose.

> **Note:**
> The input reference model automaton is encoded in the **XLIA language** (file `.xlia`), the input language of the **Diversity** symbolic execution platform. **SPTG** extends Diversity with dedicated functionality for symbolic path-guided test case generation. See tutorials/model_specification for more details.

SPTG generates the resulting **test case automaton** in the following formats:

- **Graphical format: PlantUML**
  File `PATH_TO_SPTG/examples/example02_dummy/output_h2/testcase.puml`
  Comment: This file provides a visual representation of the test case automaton, which can be rendered using PlantUML.

- **Specification language: XLIA**
  The same language used to express the reference model.
  File `PATH_TO_SPTG/examples/example02_dummy/output_h2/testcase.xlia`
  Comment: This file can be directly used for formal verification or as input to other tools that support XLIA.

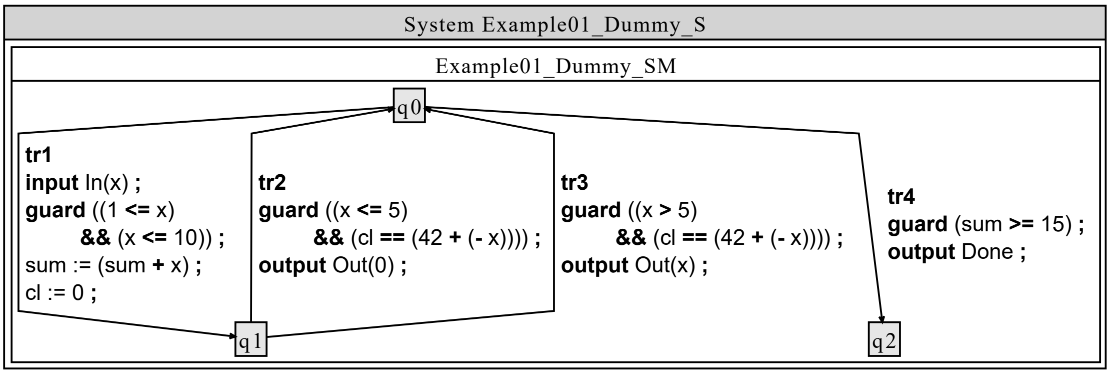
- **JSON format with SMT-LIB guards**
  File `PATH_TO_SPTG/examples/example02_dummy/output_h2/testcase_smt.json`
  Comment: This JSON file encodes the test case automaton, including guards in SMT-LIB format, suitable for automated execution againt system under test (SUT) using an SMT-solver (e.g. Z3).

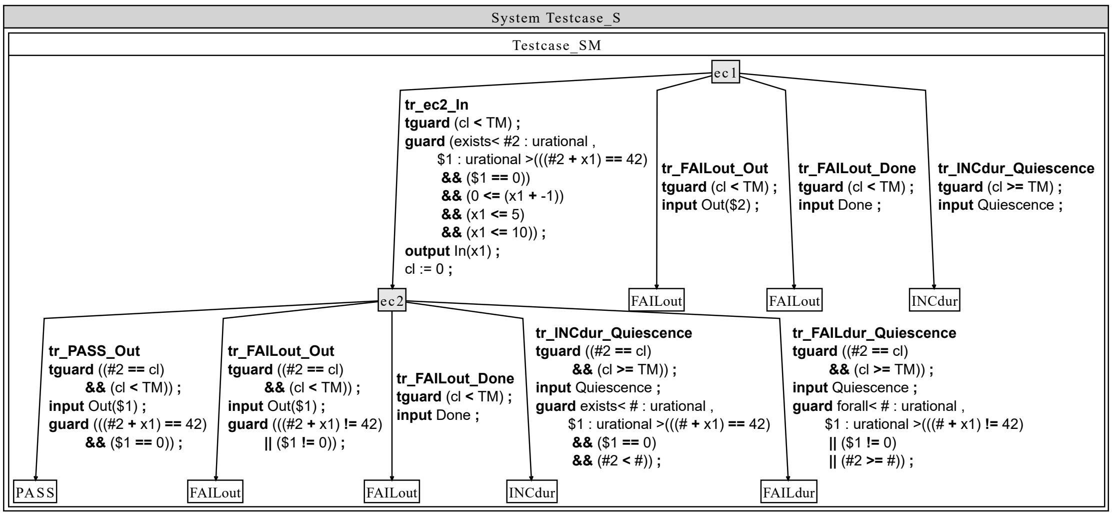
> **Note:** The script also generates the graphical **PlantUML** file for the reference automaton:
> **File** `PATH_TO_SPTG/examples/example02_dummy/output_h2/example02_dummy.puml`
> *Comment:* This file provides a visual representation of the reference automaton.

> **Note:** You can visualize `.puml` files using PlantUML or the online tool PlantText. You can convert a file `.puml` to a file `.svg` (see the PlantUML Conversion Guide).

> **Note:** If the **PlantUML JAR** is located in `PATH_TO_SPTG/bin`, the script automatically produces:
> **File** `PATH_TO_SPTG/examples/example02_dummy/testcase.svg` .

The table below summarizes the inputs and outputs for generating a **test case** with SPTG. The figures shown are **visual representations** obtained by converting the corresponding **PlantUML** files into **SVG** format.

Description	Content
Input 1: *Reference system model (Timed Symbolic Automaton)*	 System Example01_Dummy_S Example01_Dummy_SM q0 tr1 input In(x) ; guard ((1 <= x) && (x <= 10)) ; sum := (sum + x) ; cl := 0 ; tr2 guard ((x <= 5) && (cl == (42 + (- x)))) ; output Out(0) ; tr3 guard ((x > 5) && (cl == (42 + (- x)))) ; output Out(x) ; tr4 guard (sum >= 15) ; output Done ; q1 q2
Input 2: *Test purpose (Sequence of transitions)*	`tr1; tr2`

Description	Content
Output: *Generated test case (Deterministic Timed Symbolic Automaton)*	

Run all examples

```
cd PATH_TO_SPTG/examples/
run-all.sh
```

Compilation instructions

To compile SPTG, navigate to the `Release` directory of the `org.eclipse.efm.symbex` module:

```
cd PATH_TO_SPTG/org.eclipse.efm.symbex/Release/
```

Then build the project:

```
make all -j4
```

During compilation, the process automatically overwrites the existing `sptg.exe` in the `bin` directory using:

```
cp -f sptg.exe ../../bin/sptg.exe
```

If you wish to preserve the existing executable, rename it before compilation as follows:

```
mv ../../bin/sptg.exe ../../bin/sptg_old.exe
```

PlantUML: PUML to SVG Conversion Guide

A quick reference for converting `.puml` files to `.svg` images via the command line.

Prerequisites

1. **Java Runtime Environment (JRE):** Required to execute PlantUML.
2. **PlantUML JAR File:** The standalone application.

1. Download PlantUML

Get the latest stable release of `plantuml.jar` from the official github site:
☞ https://github.com/plantuml/plantuml/releases

2. Conversion Command

Navigate to the folder containing both `plantuml.jar` and your `.puml` file.

Use the `-tsvg` flag to generate an SVG image:

Command	Action
`java -jar plantuml.jar -tsvg yourfile.puml`	Converts the input file (`.puml`) to an SVG output (`.svg`).

Example

```
# Generates 'MyDiagram.svg'
java -jar plantuml.jar -tsvg MyDiagram.puml
```