

Time-optimal Real-Time Test Case Generation using UPPAAL

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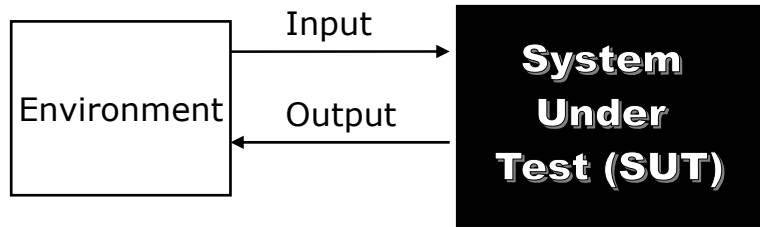
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Aalborg University



Testing

- The primary software validation technique used by industry
- Difficult and often
 - Ad hoc,
 - error prone
 - very expensive
- Time consuming
 - Optimal test suites can save a lot of time/money

Black Box Testing



Stimulus?

Coverage?

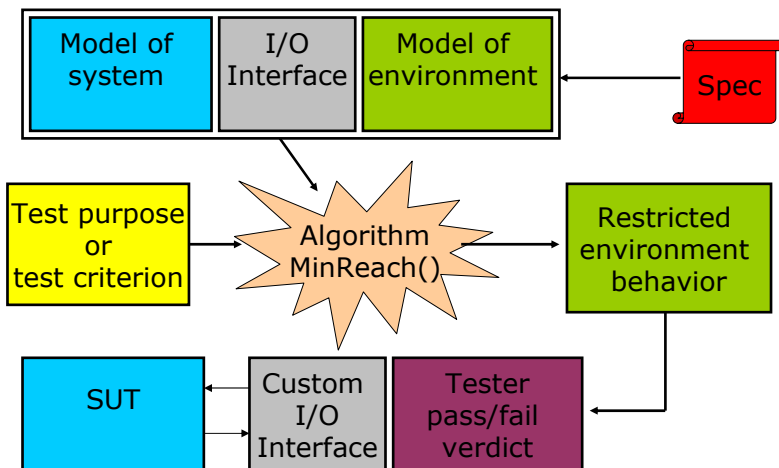
Fully tested?

Correct output?



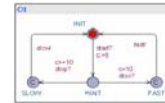
Timing issues?

Model based testing

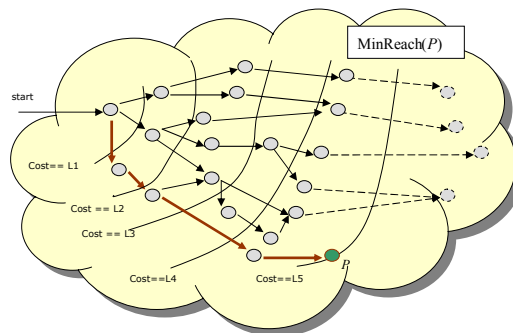
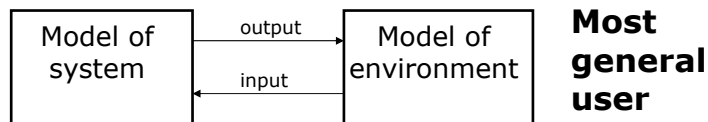


DIEOU Timed Automata

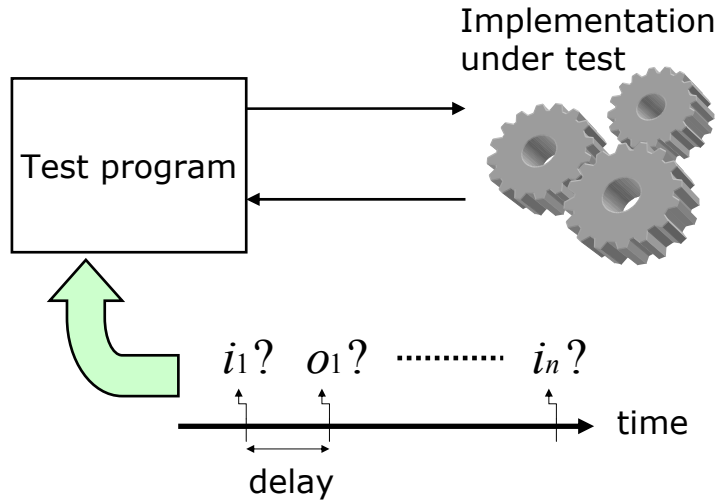
- Deterministic Timed I/O Automata:
 - **D**eterminism: Input action and the current state uniquely determines the next state.
 - **I**nput **E**nable: All inputs can always be accepted.
 - **O**utput **U**rgent: Enabled outputs will occur immediately, and any delay must have exact constant time
 - (There must be no restriction on the environment's ability to receive the output)



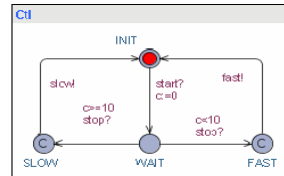
Test Case Generation



Testing Environment



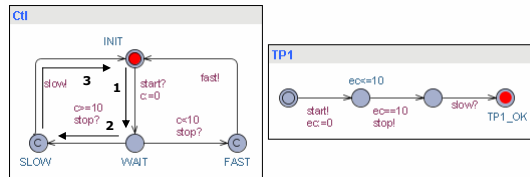
Single Purpose Test Generation



- A single objective (purpose) to test
- Examples:
 - ✱ TP1: Check that we get a *slow* output, if we: input *start*, wait 10 time units, and input *stop*, then we shall get a *slow* output
 - ✱ TP2: Check that the *fast* output can be sent by the system

Test Purpose 1

- Environment is modeled as intended behavior
- $MinReach(TP1@TP1_OK)$



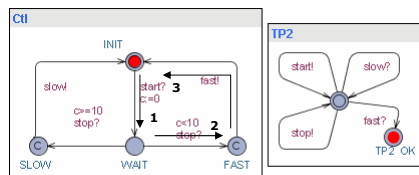
Minimal trace:

start!, delay 10, stop!, delay 0, slow?

Test Purpose 2

Check that the *fast* output can be sent by the system

- We are done when we get a *fast* output, $MinSearch(TP2.TP2_OK)$
- Environment gives Ctl maximum freedom

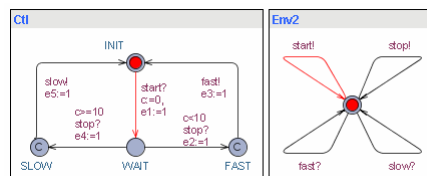


Coverage Based Test Generation

- Multi purpose test
- We search a trace where all test purposes are true at least once.
- We add auxiliary variables to the model to track each purpose e
- The auxiliary variables are monotonic over time

Edge Coverage

- Find a trace that performs every edge.
- When an edge is taken, remember the action in an auxiliary variable
- Search with *MinSearch* for a state where all edges have been taken.



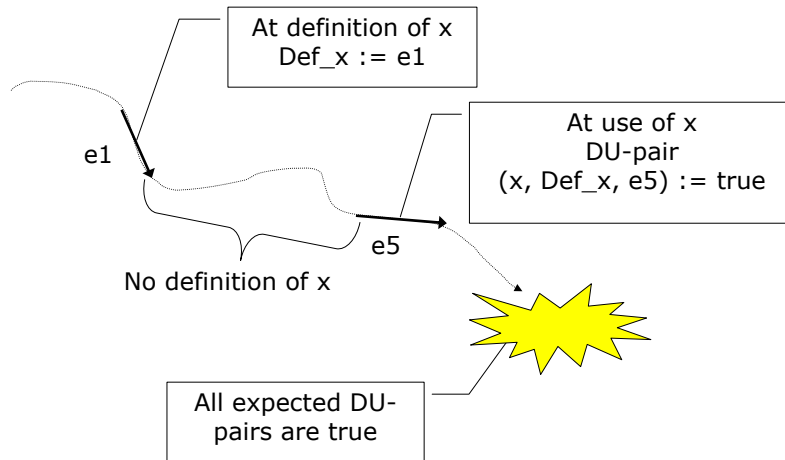
Location Coverage

- Visit every location
- Remember visits in auxiliary variables, added on incoming edges.
- Initial location is initially visited
- Search with MinSearch for a state where all locations have been visited.

Definition-Use (pair) Coverage

- Data flow technique collecting paths def-to-use for a variable so that no new definition appears in the path.
- In our case we use (x, def, use) where x is a variable and def and use are two edges.
- All uses DU pair coverage.

Definition-Use Coverage



Test Suite Generation

- We add global system reset and associate a cost (i.e. reset time)
- Performing a reset return the whole system (SUT and environment) to its initial state except for the auxiliary variables.
- MinSearch() will find the optimal combinations of test cases

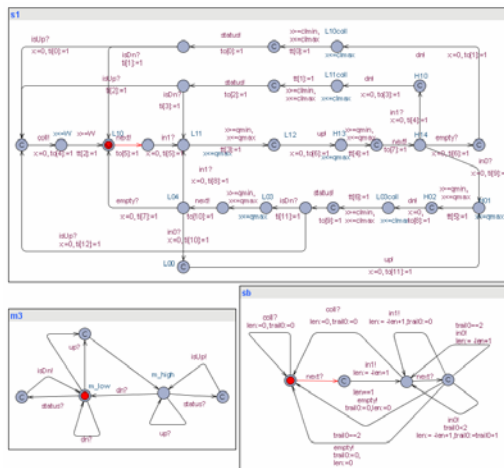
Example

Philips Audio Protocol (DIEOU TA)

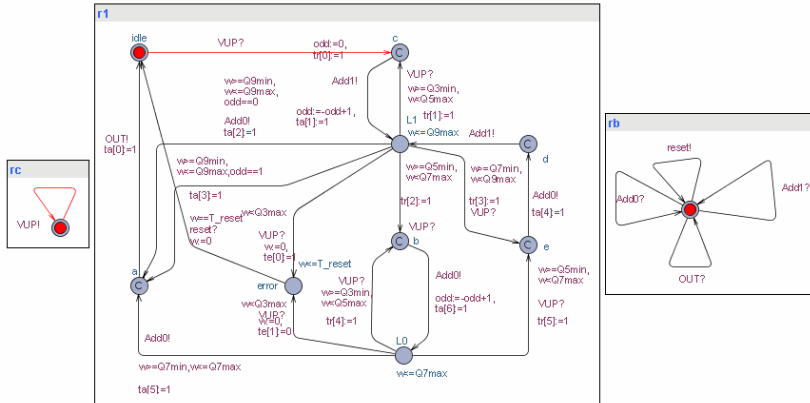
- Execution time E
- Generation time G
- Memory M
- EC = Edge Coverage

Criteria	E(μ s)	G (s)	M (Kb)
EC_S	212350	2.2	9416
EC_R	18981	1.2	4984
$EC_{R,S}$	114227	129.0	331408

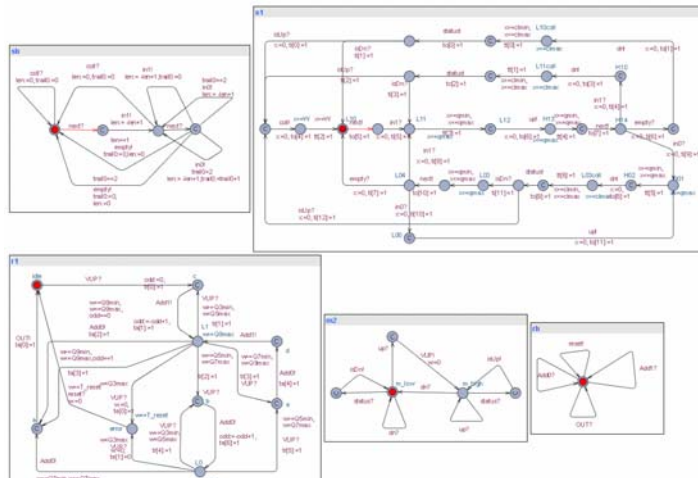
Philips spontaneous



Philips chaotic



Philips correct env



Implementation

- UPPAAL verifier extension
- On-the-fly annotation of symbolic state space
- Monotonic behavior of annotation
 - ✿ Up to 67% reduction of run-time
 - ✿ Up to 45% reduction of space

Conclusions

- We generate test cases as sequences of input/output with timing
- We have shown how the technique can be used in UPPAAL to generate test cases for three important coverage criteria.
- Performance is encouraging.
- Time optimal test suites can be obtained

Current/Future Work

- Adding to the modeling language monotonic and hidden variables (for encoding)
- Projection state coverage
- Relax urgency requirement of the model
- Case Studies

Related work

- Clarke and Lee
- En-Nouaary, Dssouli and Khendek
- Mandrioli, Morasca, and Morzenti
- Springintveld, Vaandrager, and D'Argenio
- Tretman, Brinksma, Uyar, Hong, Cardell-Oliver