Formal Verification of DEV&DESS Formalism using Symbolic Model Checker HyTech

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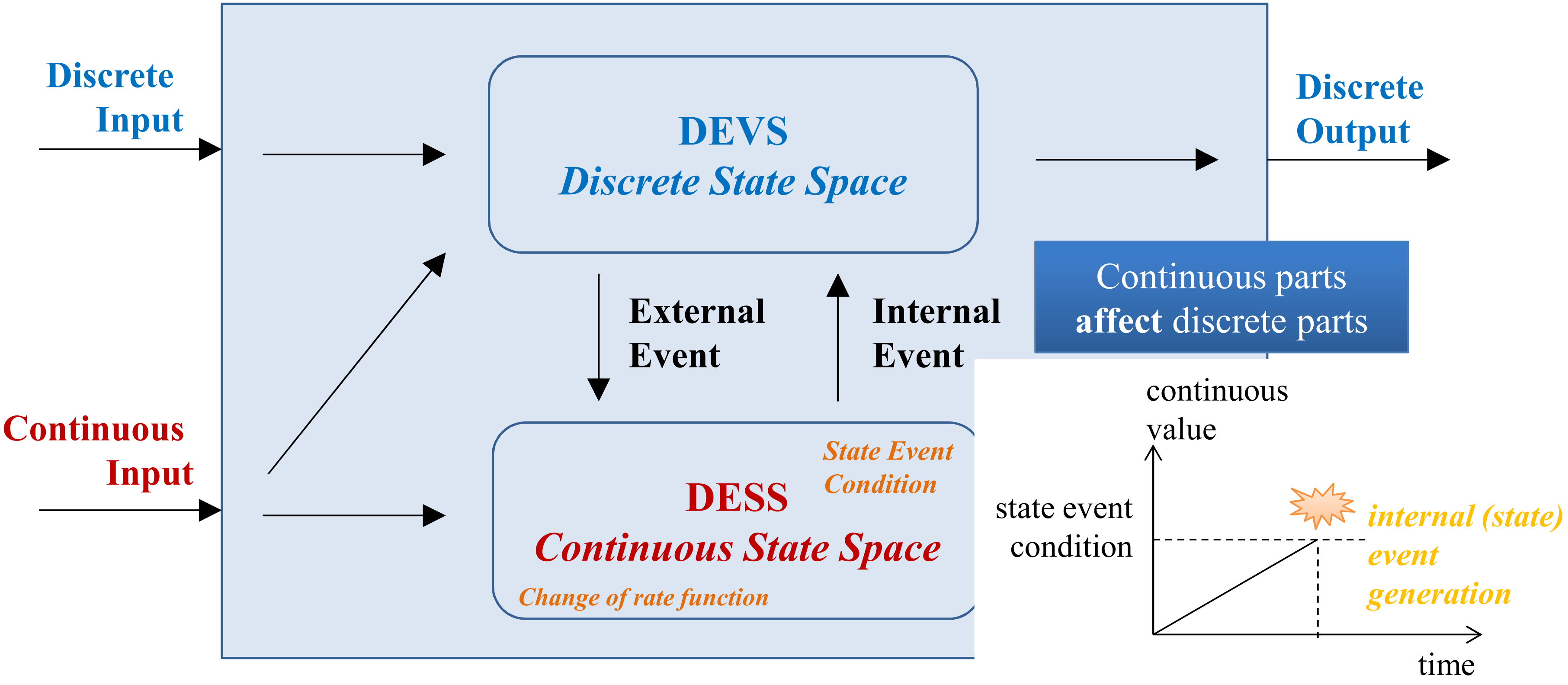
Abstraction

- Hybrid system
  - a combination of discrete and continuous dynamics
- Various algorithmic verification tools for model checking
  - e.g. HyTech: model checking tool for linear hybrid automata
- Widely used formalism for modeling hybrid systems - DEV&DESS
  - no verification tools for DEV&DESS formalism

→ We translated an example of hybrid system modeled in DEV&DESS formalism into linear hybrid automata and verified it using HyTech.

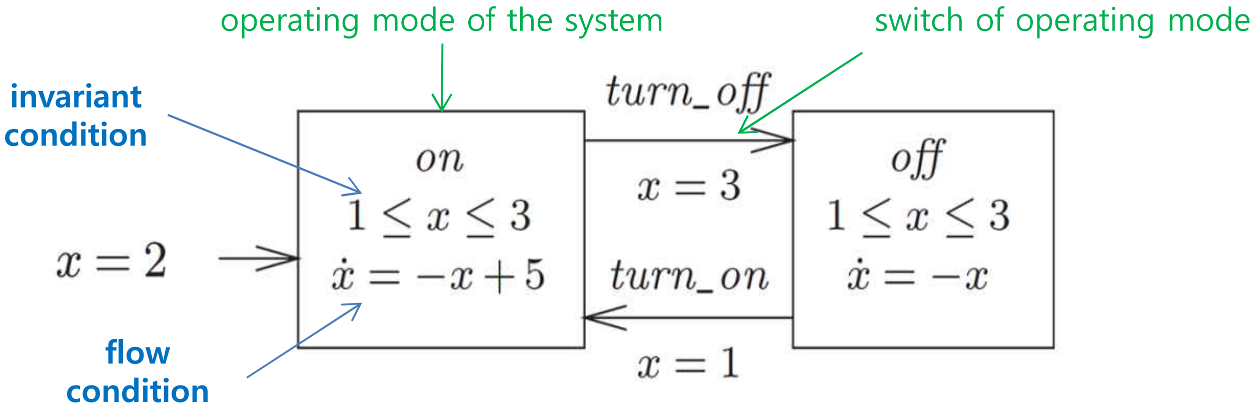
Background – DEV&DESS formalism



<An Overview of Discrete EVent & Differential Equation System Specification>

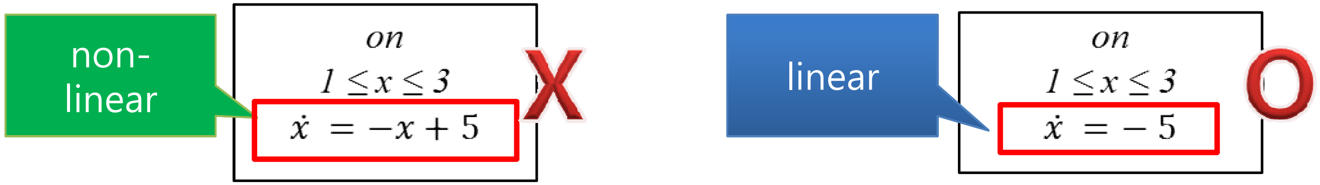
Background – Linear Hybrid Automata

- Hybrid automata
  - finite state automata with conditions on real-valued variables



<An example of hybrid automata>

- Linear hybrid automata
  - restricted class of hybrid automata

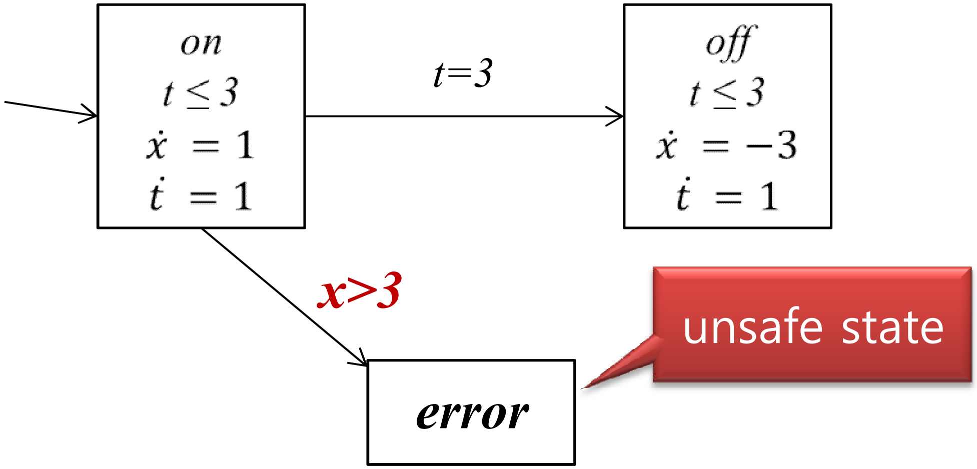


<Requirements for linear hybrid automata>

HyTech – Model Checker for Linear Hybrid Automata

- HyTech
  - symbolic model checker for linear hybrid automata
  - model checking of safety requirements and parametric analysis

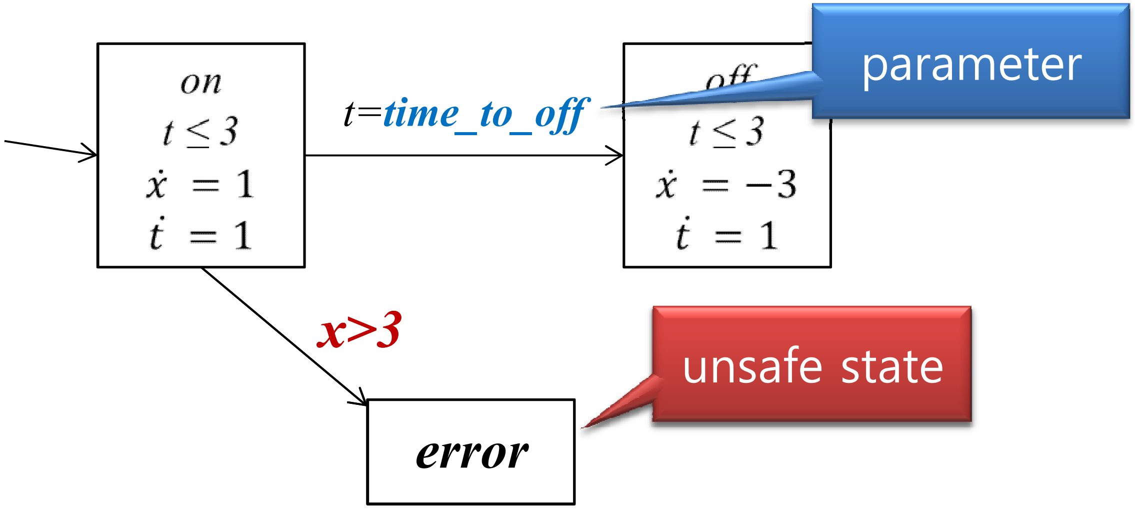
Safety requirement



HyTech – Model Checker for Linear Hybrid Automata

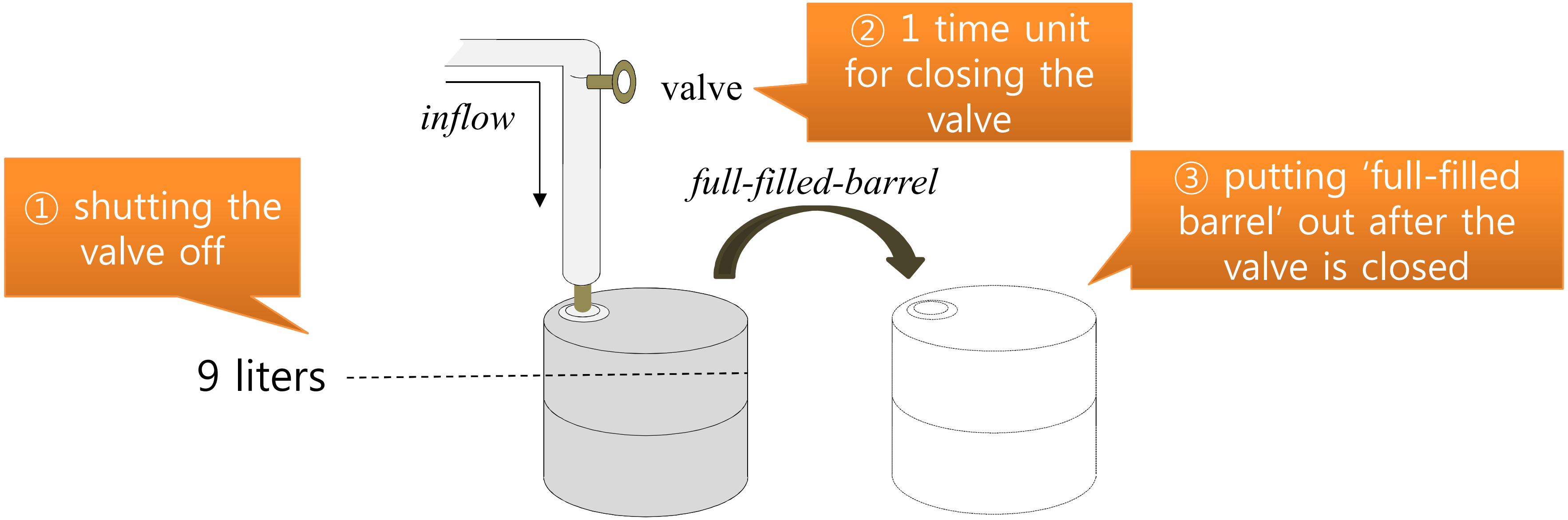
- HyTech
  - symbolic model checker for linear hybrid automata
  - model checking of safety requirements and parametric analysis

Parametric analysis



Example model – Barrel Filler System

- Characteristics of the barrel filler system
  - continuous input ‘inflow’ : 0.5 (valve - open), 0.25 (valve - closing)
  - 1 time unit for closing the valve
  - 10-liter barrel



① shutting the valve off

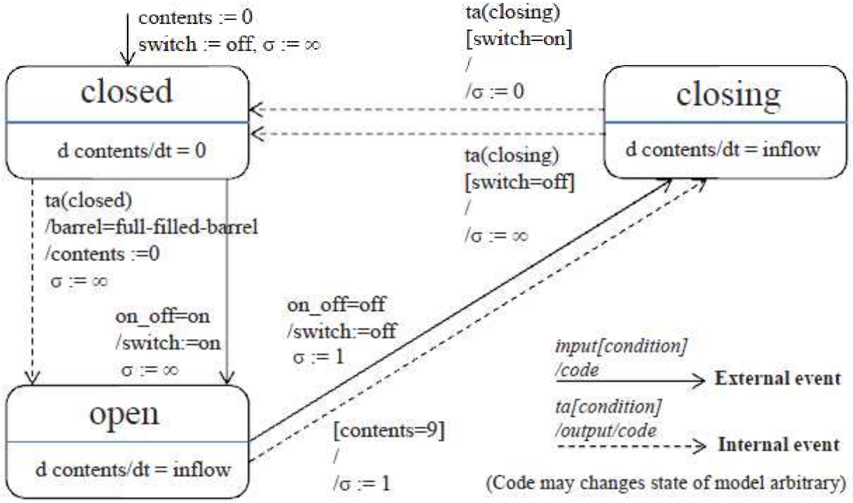
② 1 time unit for closing the valve

③ putting ‘full-filled barrel’ out after the valve is closed

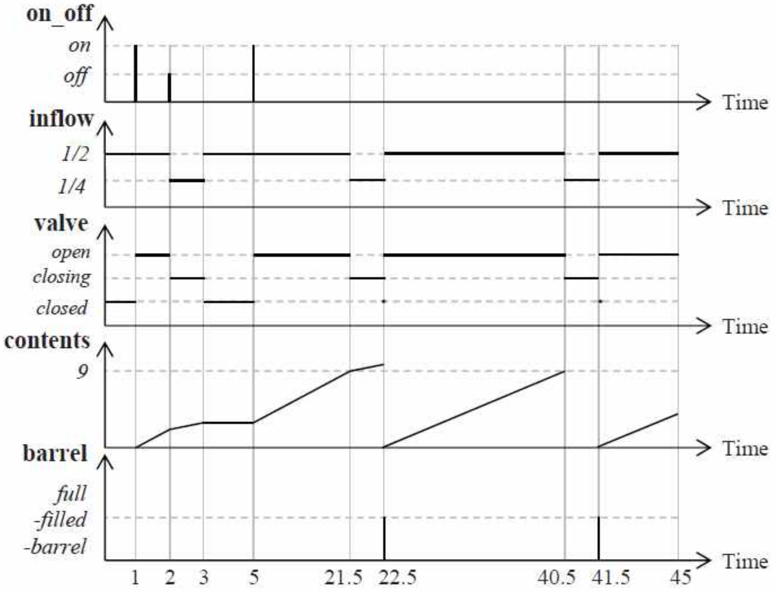
<The barrel filler system>

DEV&DESS model for the barrel filler system(1)

- Correctness of the model’s behavior
  - simulation using scenarios
  - draw trajectories for the barrel filler model



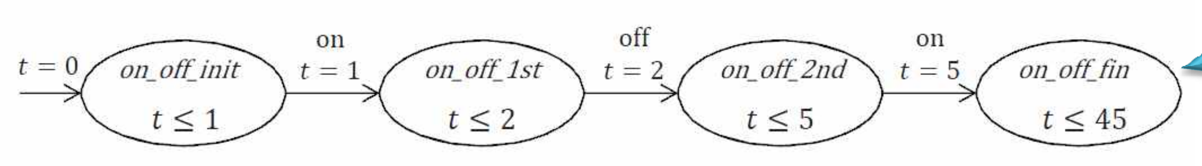
<Graphical representation of barrel filler model>



<Trajectories of the specific scenario>

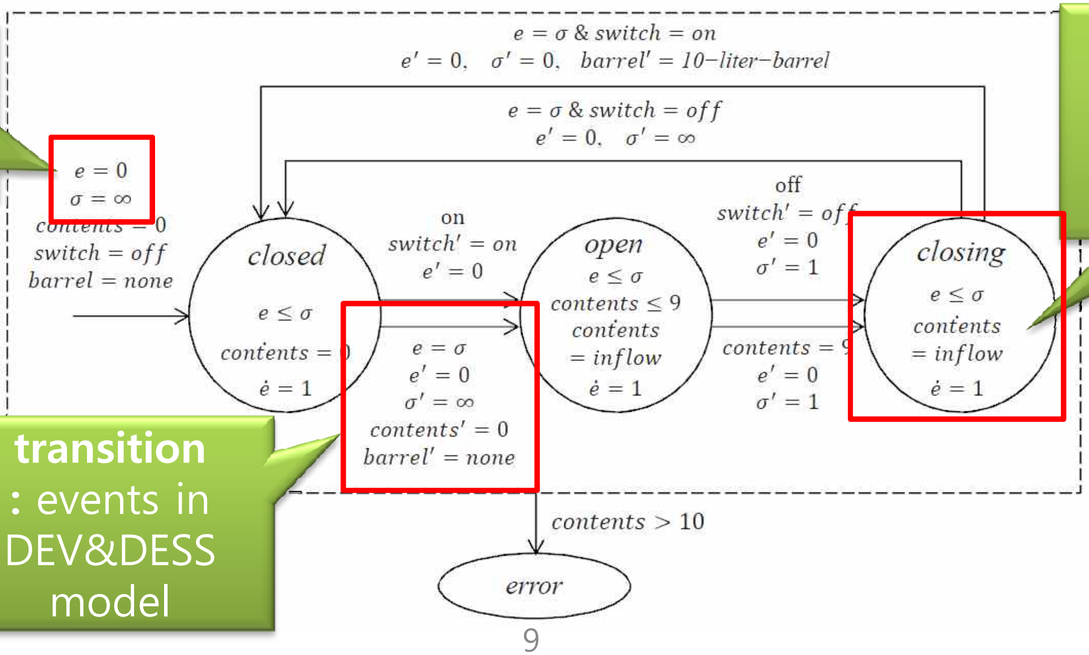
Translation DEV&DESS model into Linear hybrid automata

- Parallel composition of automata for input ports



used for validation of translation (specific scenario)

- Translation the barrel filler model into linear hybrid automata



‘e’ and ‘σ’ for time events

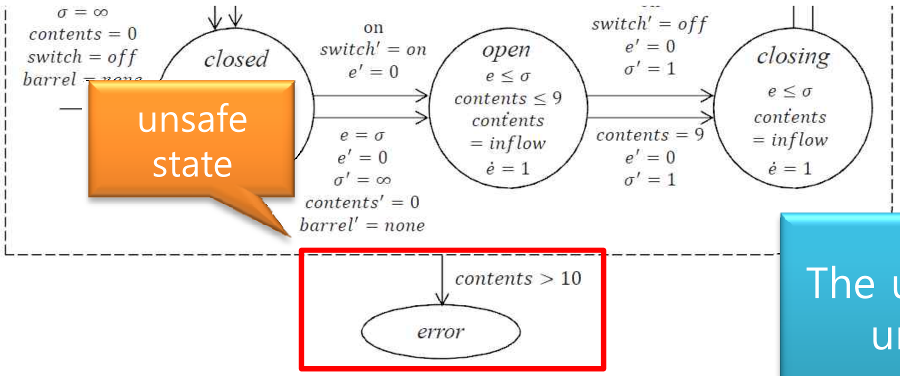
node
: Phase in DEV&DESS model

transition
: events in DEV&DESS model

Verification of Barrel Filler System using HyTech (1)

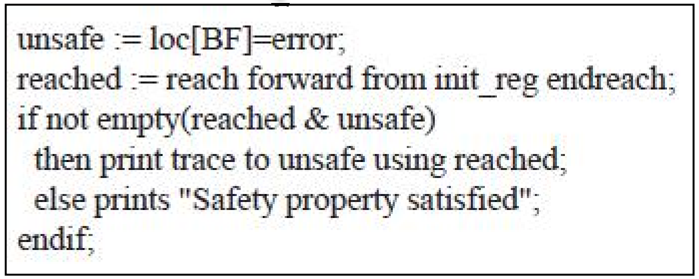
- Statement for the safety requirement

'Content of a barrel should be under 10 liters'



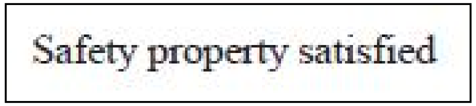
Checking whether the unsafe state can be reached

The unsafe state is unreachable



```
unsafe := loc[BF]=error;
reached := reach forward from init_reg endreach;
if not empty(reached & unsafe)
  then print trace to unsafe using reached;
  else prints "Safety property satisfied";
endif;
```

<HyTech commands for safety requirement>



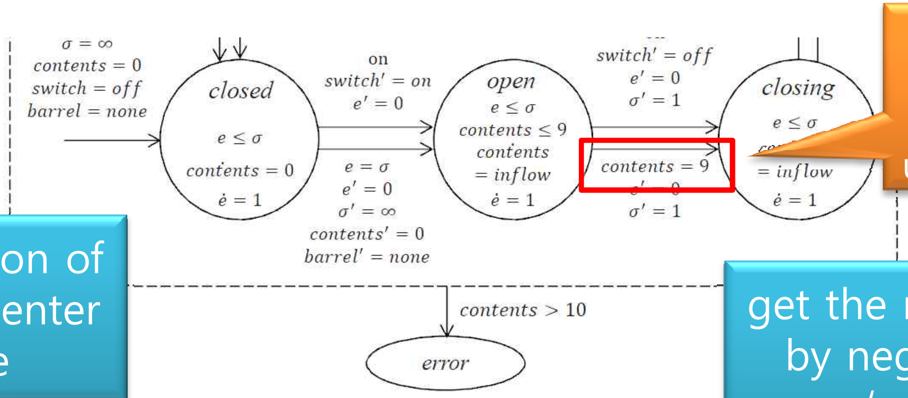
```
Safety property satisfied
```

<The result of HyTech execution>

Verification of Barrel Filler System using HyTech (2)

- Statement for parametric analysis

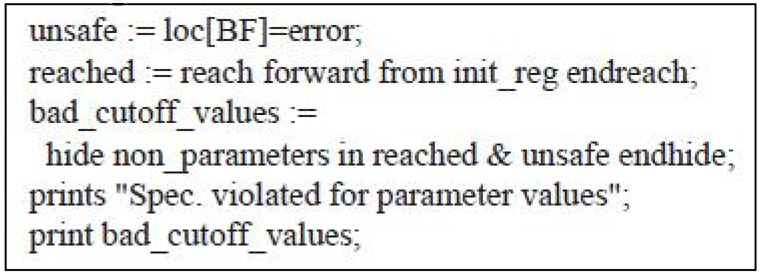
'When should the valve start closing to avoid overflowing?"'



changing the state event condition 'contents = cutoff' using parameter 'cutoff'

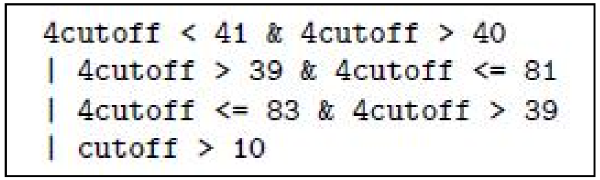
checking the condition of the 'cutoff' value to enter the unsafe state

get the right 'cutoff' value by negating the result 'cutoff > 9.75'



```
unsafe := loc[BF]=error;
reached := reach forward from init_reg endreach;
bad_cutoff_values :=
  hide non_parameters in reached & unsafe endhide;
prints "Spec. violated for parameter values";
print bad_cutoff_values;
```

<HyTech commands for parametric analysis>



```
4cutoff < 41 & 4cutoff > 40
| 4cutoff > 39 & 4cutoff <= 81
| 4cutoff <= 83 & 4cutoff > 39
| cutoff > 10
```

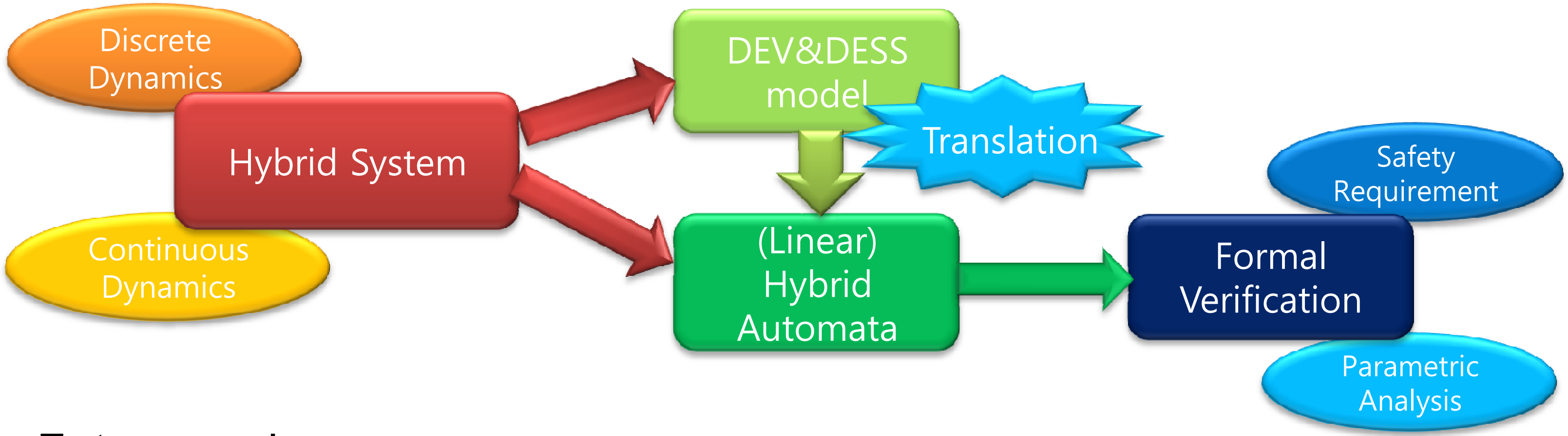
<The result of parametric analysis>

Further considerations on the translation

- Expressing the confliction between events in linear hybrid automata
  - lack of ability to assign the order of priority between transitions in hybrid automata
- Preprocessing of the continuous input trajectories
  - limitation of using variable in the expression of flow condition in HyTech
- Problem of the state space explosion
  - parallel composition of input automata

Conclusion and Future Work

- Formal verification of atomic DEV&DESS model
  - translation atomic DEV&DESS model into linear hybrid automata
  - performing model checking by using existing tool, HyTech



- Future work
  - translation for coupled DEV&DESS model
  - translation rules for the broad applications
  - development of automatic translation tool

Thank you for listening