Correctness of FormlSlicer

FormlSlicer: A Model Slicing Tool to Support Feature-oriented Requirements in Software Product Line

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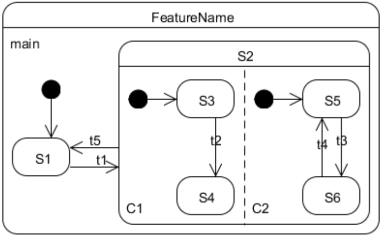
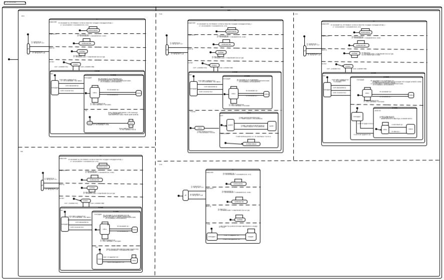
Feature Modules in FORML



The model consists of many feature modules.

We treat each feature module as an independent state machine.

Model



We treat the whole model as a state machine as well. Each feature is a sub-state machine in one orthogonal region.

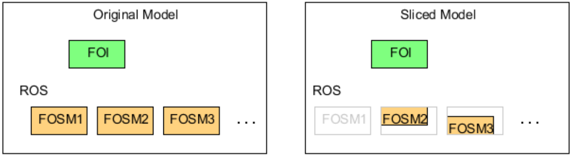
FormlSlicer: the Tool Developed

We have a tool that goes through multiple stages in performing slicing.
Generally, it starts from an empty slice set $\mathcal{L}$ and gradually adds model components into it.

A Comparision between the Original and Sliced Model

FOI = Feature of Interest
$FOSM$ = Feature-oriented State Machine
ROS = Rest of System

The sliced model is (likely) to be smaller than the original model.



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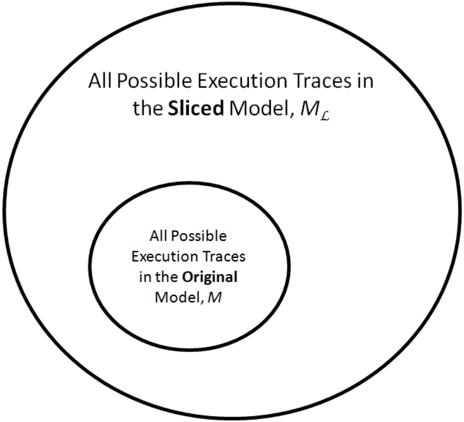
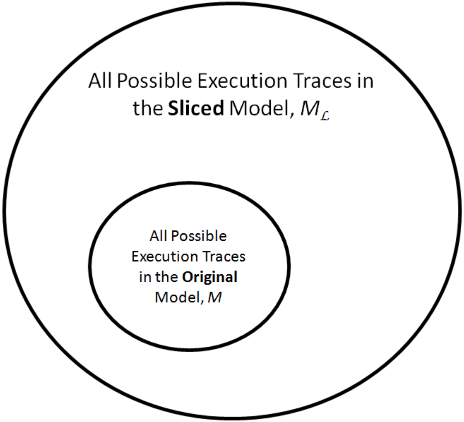
Purpose of the Proof



$$M_{\mathcal{L}} \models \varphi \Rightarrow M \models \varphi$$

Purpose of the Proof



Any given execution trace in original model can be *simulated* by an execution trace in the sliced model.

Purpose of the Proof

An execution trace in the original model is a long sequence of execution steps:

$$e_0, e_1, e_2, \ldots, e_k$$

Each e in the original model can be projected to an $e_{\mathcal{L}}$ in the sliced model:

$$P(e) = e_{\mathcal{L}}$$

Purpose of the Proof

So how can we show this?

$$P(e) = e_{\mathcal{L}}$$

We need to define some semantics first.

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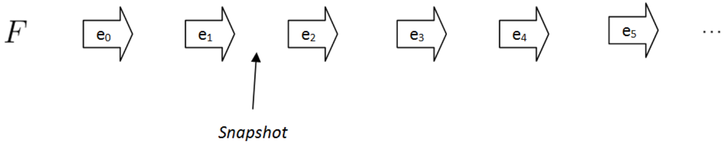
Snapshot



Informally, a **snapshot** is an observable point in a model's execution; it refers to the status of a model between execution steps.

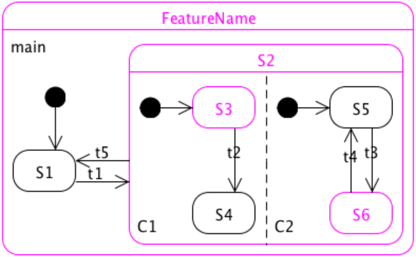
Snapshot

We define the snapshot of a model as a combination of

- the state configuration of the model, N,
- and the interpretation of variables, σ.

What are N and σ?

State Configuration, N



$N =$ $[FeatureName, S2, S3, S6]$.

Interpretation, σ

σ maps variables to their values.

$\sigma(v)$ represent the interpretation of the variable v in the environment.

Snapshot

A snapshot $= (N, \sigma)$.

the current state configuration $+$ the values of all variables

An Execution Step, e

An execution step e changes the current snapshot from (N, σ) evolves to (N', σ').

$$M_{\mathcal{L}} \vdash e : (N, \sigma) \longrightarrow (N', \sigma')$$

An Execution Step, e

Each execution step involves a set of transitions which occur concurrently, denoted as:

$$e = \begin{array}{c} t_1 \\ \vdots \\ t_k \end{array}$$

If $k = 1$? we write $e = t$. **Non-concurrent Execution Step**.
If $k > 1$?

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Projection of an Execution Step

In order to show

$$P(e) = e_{\mathcal{L}}$$

We will show

$$P(e) = P\begin{pmatrix} t_1 \\ \vdots \\ t_k \end{pmatrix} = \begin{pmatrix} P(t_1) \\ \vdots \\ P(t_k) \end{pmatrix} = e_{\mathcal{L}}$$

Projection of a Transition

Then we need to show $P(t) = (\epsilon \vee t_{\mathcal{L}})$

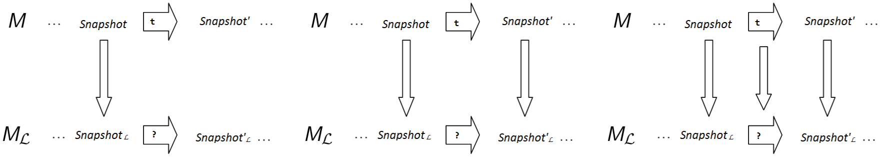
A transition in the original model is projected to epsilon or another transition in the sliced model.

Projection of a Transition

$P(t) = (\epsilon \vee t_{\mathcal{L}})$, if:

Before the transition, the snapshot of original model is projected to the snapshot in sliced model;

After the transition, the snapshot of original model is still projected to the snapshot in sliced model.



Projection of Snapshot

How can we know a snapshot of the original model, (N, σ), is projected to a snapshot of the sliced model, $(N_{\mathcal{L}}, \sigma_{\mathcal{L}})$?

Projection of Snapshot

We define $P((N, \sigma)) = ((N_{\mathcal{L}}, \sigma_{\mathcal{L}}))$, when

- there is a relation between their state configurations, N and $N_{\mathcal{L}}$;
- $\sigma(v) = \sigma_{\mathcal{L}}(v)$ for a relevant variable v.

Projection of Snapshot

We define $P((N,\sigma)) = ((N_{\mathcal{L}}, \sigma_{\mathcal{L}}))$, when

- there is a relation between their state configurations, N and $N_{\mathcal{L}}$; <== Use State Transition Rule to Prove!
- $\sigma(v) = \sigma_{\mathcal{L}}(v)$ for a relevant variable v.<== Only relevant variables are concerned!

State Transition Rule

The state transition rule defines how the current state configuration N evolves to the next state configuration N' through an execution step.

$$N' = (N - exited(t)) \cup entered(t)$$

N and N are the current and next state configuration of the model.

State Transition Rule

$$N' = (N - exited(t)) \cup entered(t)$$

$exited(t)$:

- the source state itself, $ss(t)$;
- the ancestor states of $ss(t)$ up along the tree of state hierarchy before reaching the least common ancestor with $ds(t)$;
- the descendant states of $ss(t)$.

State Transition Rule

$$N' = (N - exited(t)) \cup entered(t)$$

$entered(t)$:

- the destination state itself, $ds(t)$;
- the ancestor states of $ds(t)$ up along the tree of state hierarchy before reaching the least common ancestor with $ss(t)$;
- the recursively identified default start states of $ds(t)$ and its entered descendant states.

Relevant Variables

Relevant variables are a set of variables that directly or indirectly influence the Feature of Interest (FOI).
They are selected using Data Dependence.

Roadmap So Far...

Projection of an execution step

<== Projection of a transition inside the execution step

<== Projection of a snapshot before and after the transition

<== State configuration and interpretation of the snapshot

<== state configuration: using state transition rule and steps in FormlSlicer

<== interpretation: using relevant variables and data dependency of FormlSlicer

Projection of a Transition

We will divide into 7 cases to show $P(t) = (\epsilon \vee t_{\mathcal{L}})$.

$$P(t) = \begin{cases} t_{true} & \text{if } (t \notin \mathcal{L}) \wedge (\neg SameParent(t)) & (1) \\ \epsilon & \text{if } (ss(t) \in \mathcal{L}) \wedge (ds(t), t \notin \mathcal{L}) \wedge (SameParent(t)) & (2) \\ \epsilon & \text{if } (ss(t), ds(t), t) \notin \mathcal{L} \wedge (SameParent(t)) & (3) \\ t_{true} & \text{if } (ss(t), t \notin \mathcal{L}) \wedge (ds(t) \in \mathcal{L}) \wedge (SameParent(t)) & (4) \\ t_{true} & \text{if } (ss(t), ds(t) \in \mathcal{L}) \wedge (t \notin \mathcal{L})) \wedge (SameParent(t)) & (5) \\ \epsilon & \text{if } (n_{merged} = (ss(t) \vee ds(t)) \in \mathcal{L} & (6) \\ t & \text{if otherwise} & (7) \end{cases}$$

Projection of a Transition

We have 7 sub-proofs for each case (i) from (1) to (7). Each is in the following format:

Given the projection of a snapshot before t.

- Because of Step XXX in FormlSlicer, *entered*(t) will appear in the state configuration of the sliced model...
- Because of Data Dependence in FormlSlicer, $\sigma(v)$ will change value in the same fashion in the sliced model...

$=>$ the projection of a snapshot after t.
$=>$ $P(t) = (\epsilon \vee t_{\mathcal{L}})$ for Case (i)

Projection of an Execution Step

$$P(e) = P\begin{pmatrix} t_1 \\ \vdots \\ t_k \end{pmatrix} = \begin{pmatrix} P(t_1) \\ \vdots \\ P(t_k) \end{pmatrix} = e_{\mathcal{L}}$$

Note that $P(t) = (\epsilon \vee t_{\mathcal{L}})$.

Induction

Base Case:
The initial snapshot in original model can be projected to the initial snapshot in the sliced model.

Inductive Case:
$P(e) = e_{\mathcal{L}}$, such that snapshot in original remains projected to the snapshot in the sliced model.

Conclusion:
The execution trace in original model can be *simulated* by an execution trace in sliced model.


THANK YOU