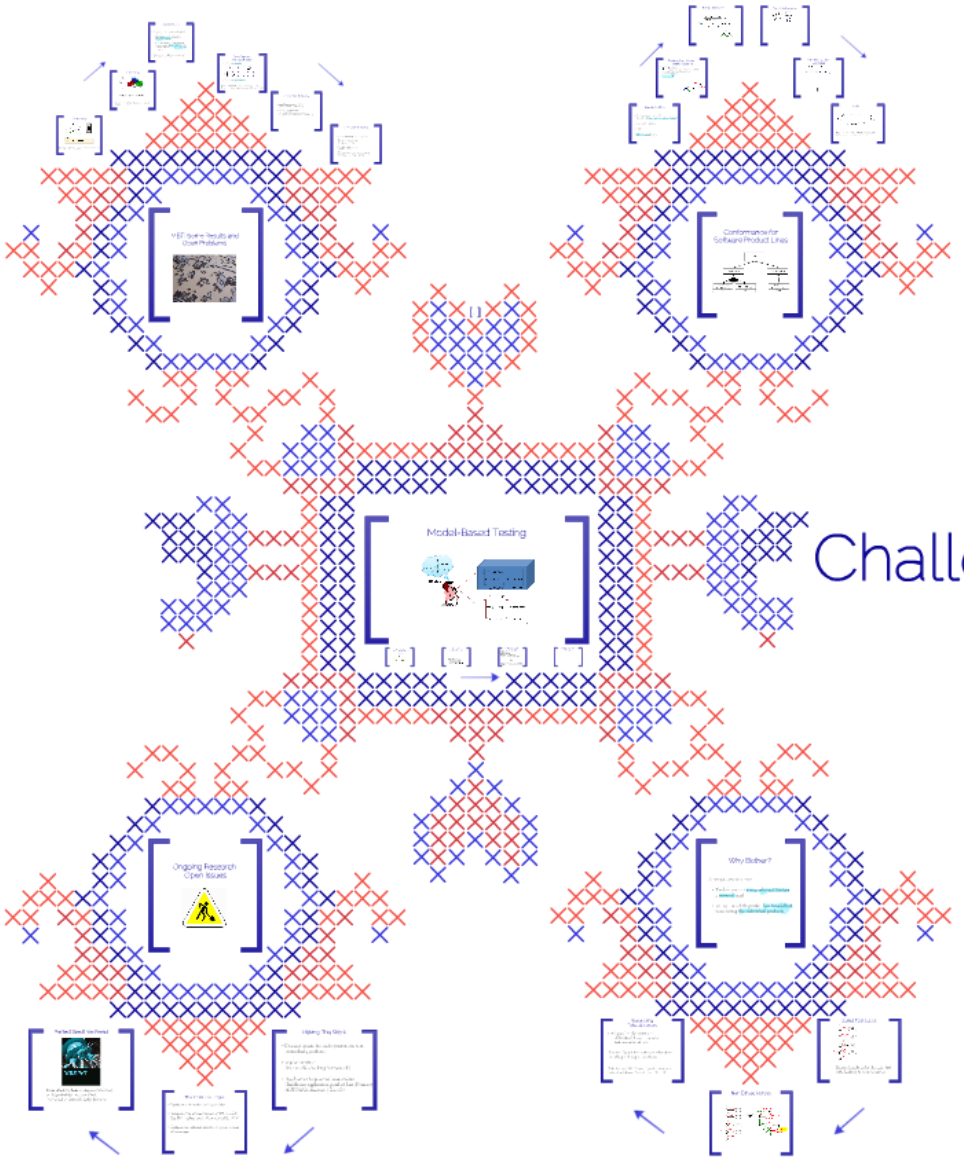

Challenges in Model-Based Testing of Software Product Lines

Harsh Beohar
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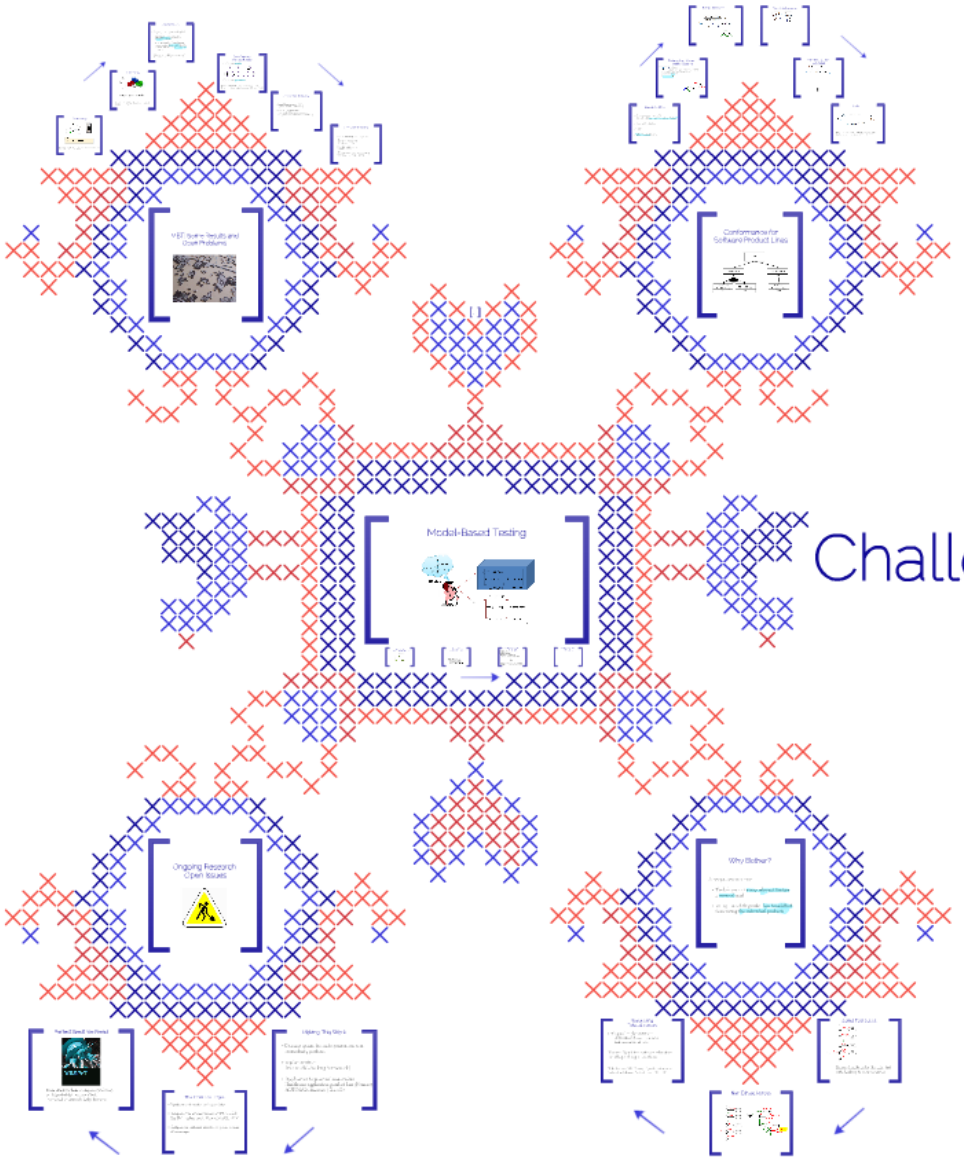
Halmstad University



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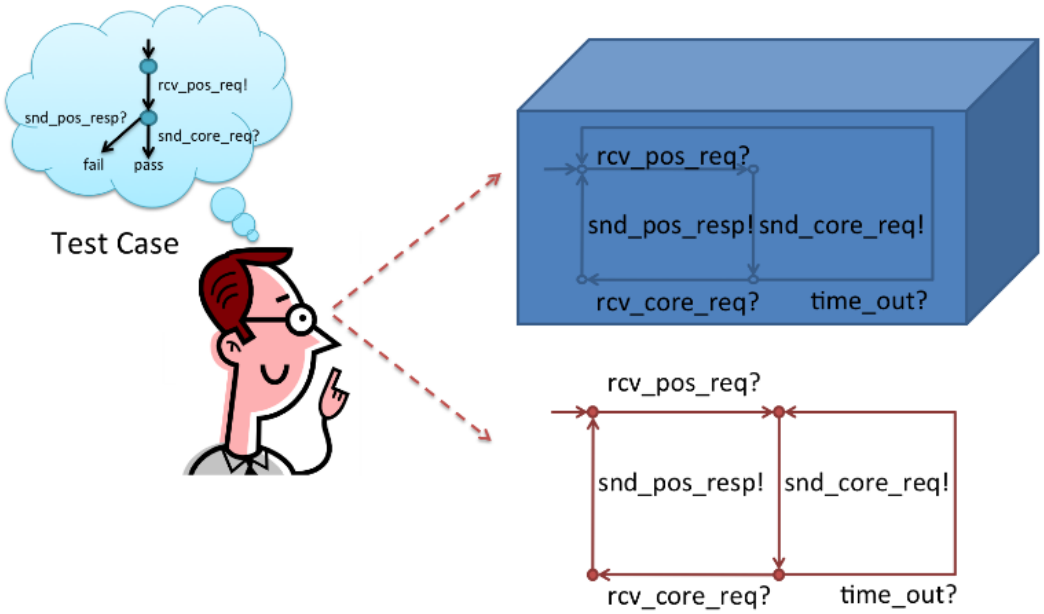
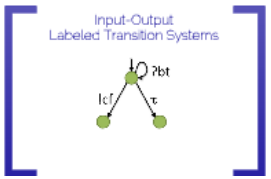
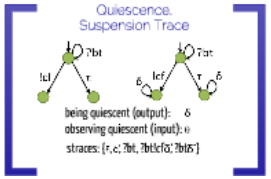
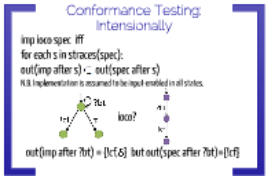
Model-Based Testing

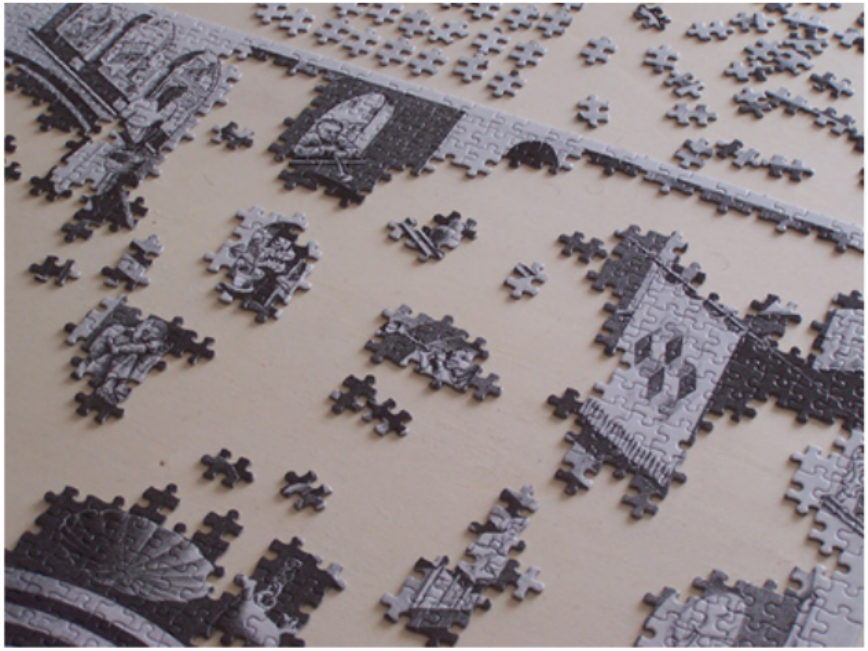




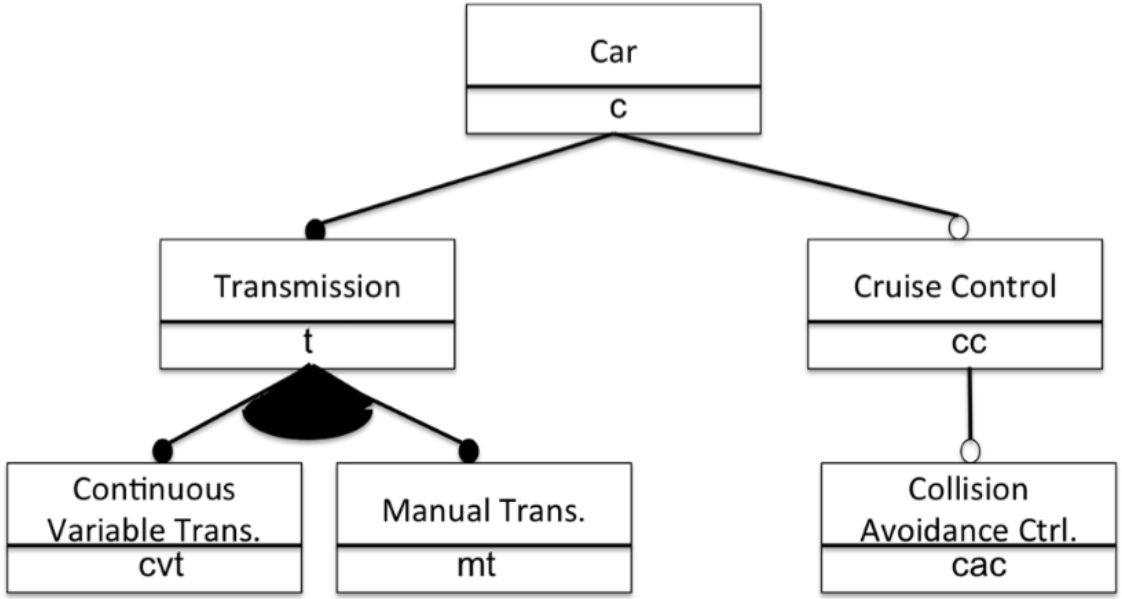




MBT: Some Results and Open Problems



Conformance for Software Product Lines



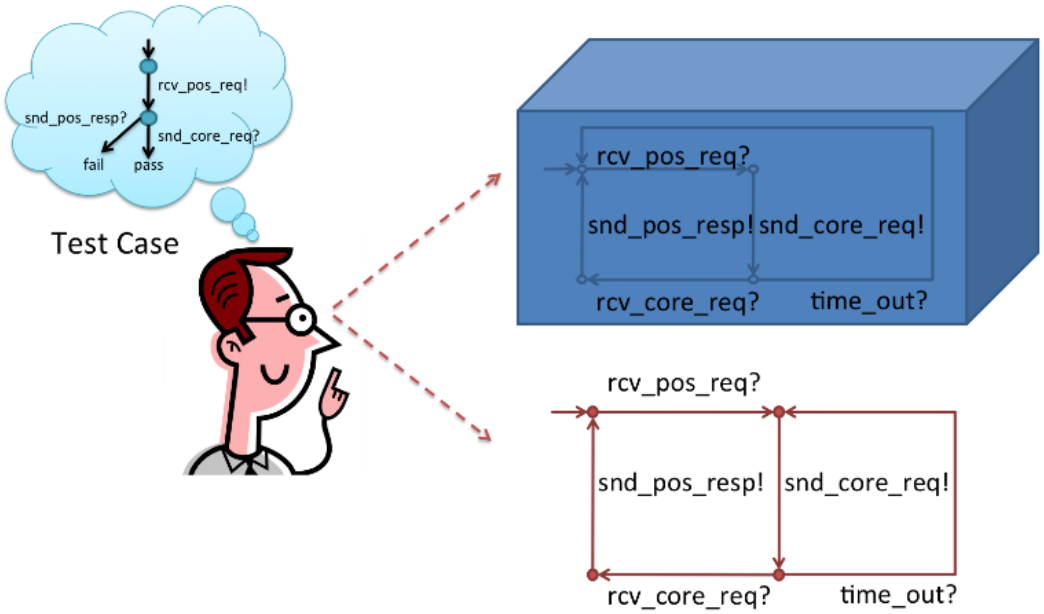
Why Bother?

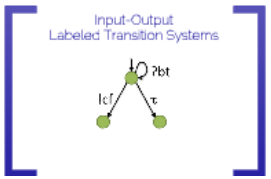
A test process such that:

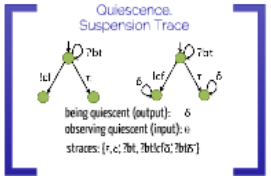
- The behavior of **every relevant feature** is **covered**, and
- testing the whole product **less time/effort** than testing **the individual products**.

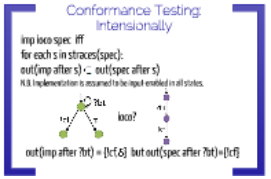
Ongoing Research
Open Issues

Model-Based Testing

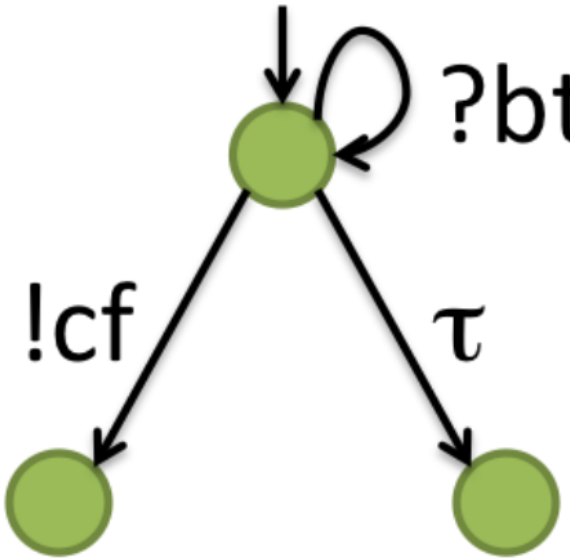




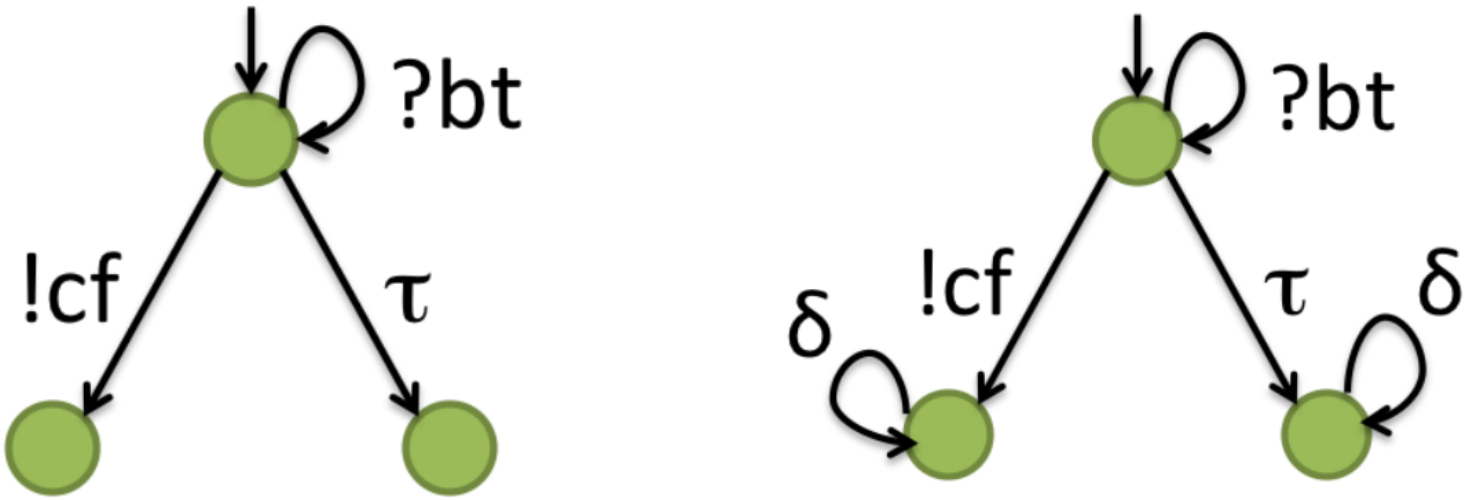




Input-Output Labeled Transition Systems



Quiescence, Suspension Trace



being quiescent (output): δ

observing quiescent (input): θ

straces: $\{\varepsilon, \delta^*, ?bt, ?bt!cf\delta^*, ?bt\delta^*\}$

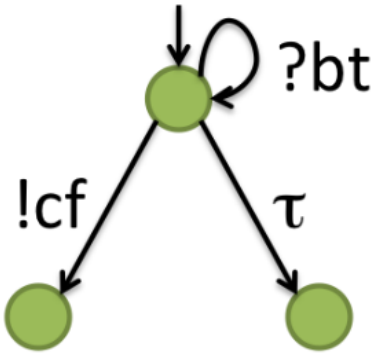
Conformance Testing: Intensionally

imp ioco spec iff

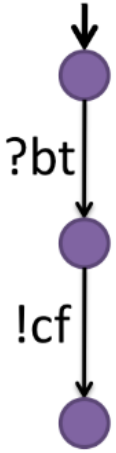
for each s in straces(spec):

out(imp after s) $\subseteq$ out(spec after s)

N.B. Implementation is assumed to be input-enabled in all states.

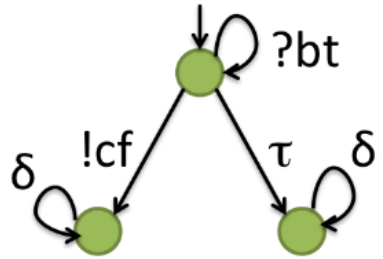


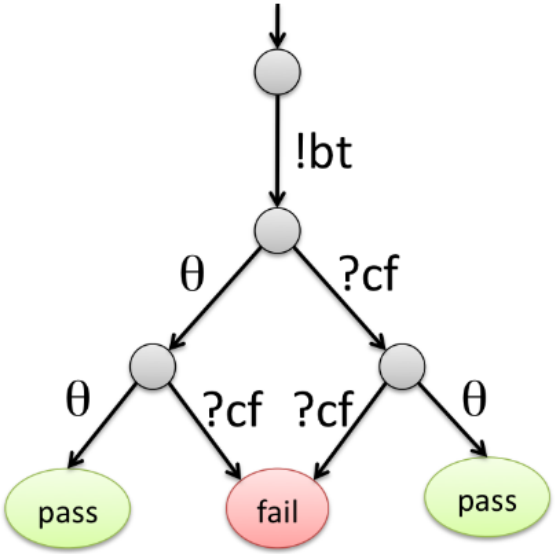
ioco?

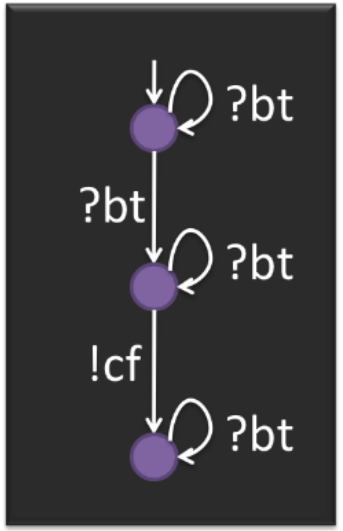


out(imp after ?bt) = {!cf,δ} but out(spec after ?bt)={!cf}

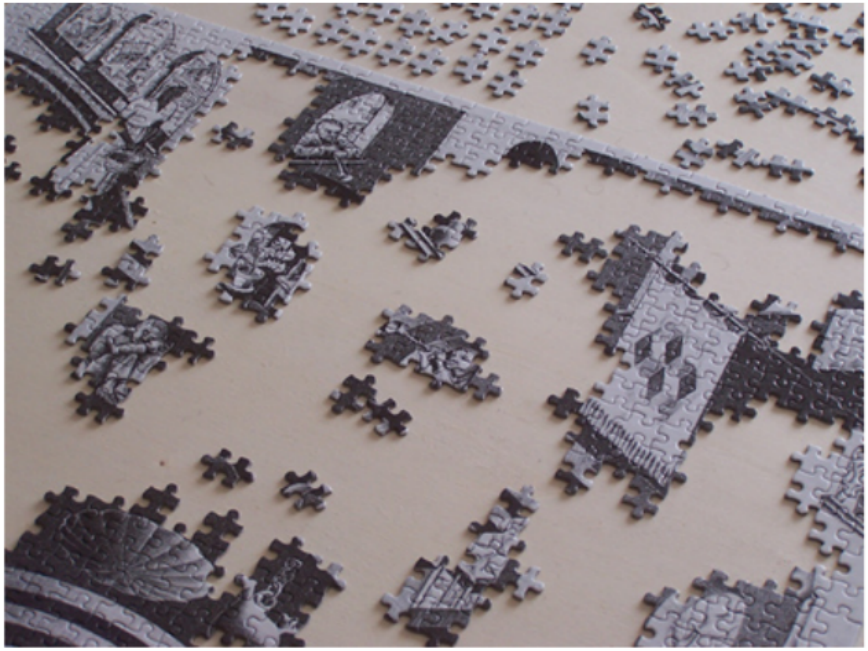
Conformance Testing: Extensionally



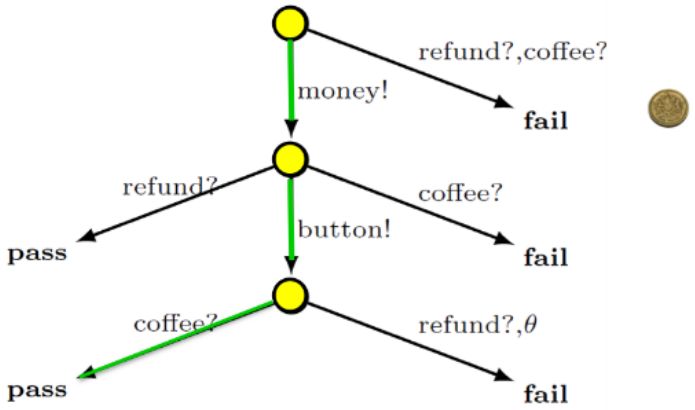




MBT: Some Results and Open Problems



Asynchrony



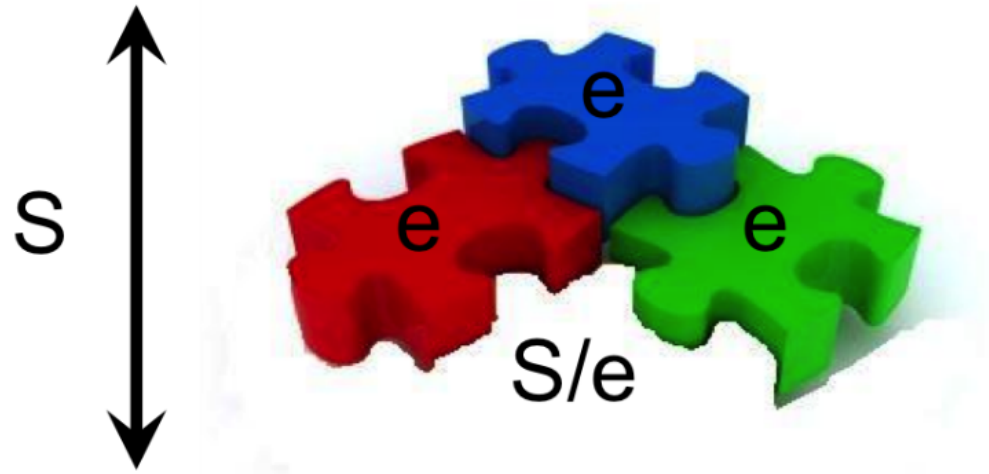
Theorem

Implementation **i** is delay right-closed iff

∀ spec: **i** *ioco* spec if and only if **Q(i)** *ioco* spec

N. Noroozi, R. Khosravi, MRM, T. Willemse, Synchrony and Asynchrony in Conformance Testing, SoSym J., 2014.

Quotienting



for all c, (c || e) ioco s iff c ioco S/e

N. Noroozi, MRM, T. Willemse, Decomposability in Input-Output Conformance Testing, Proc. of MBT 2013.

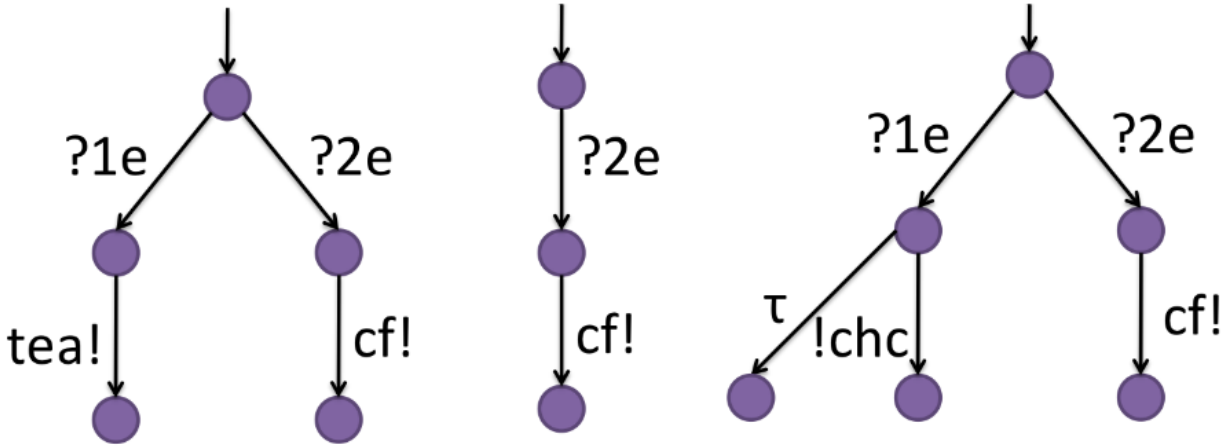
Other Results

- Complexity hierarchy for checking IOCO:
  - checking IOCO (in general) is **PSPACE-Complete**
  - for a **restricted** set of **specifications**, IOCO becomes **polynomial** (through a linear reduction to a simulation-like pre-order)

N. Noroozi, MRM, T. Willemse, On the Complexity of Input-Output Conformance Testing, Proc. of FACS 2013.

Open Problem: Compositionality

- IOCO is not a **pre-order**!



- IOCO is not a **pre-congruence**!

[M. van der Bijl, A. Rensink, J. Tretmans: FATES'03]
[P. Daca, T. Henzinger, W. Krenn and D. Nickovic ICST'14]

Other Open Problems

- **Logical characterization** of IOCO
  (ongoing work by Harsh Beohar)

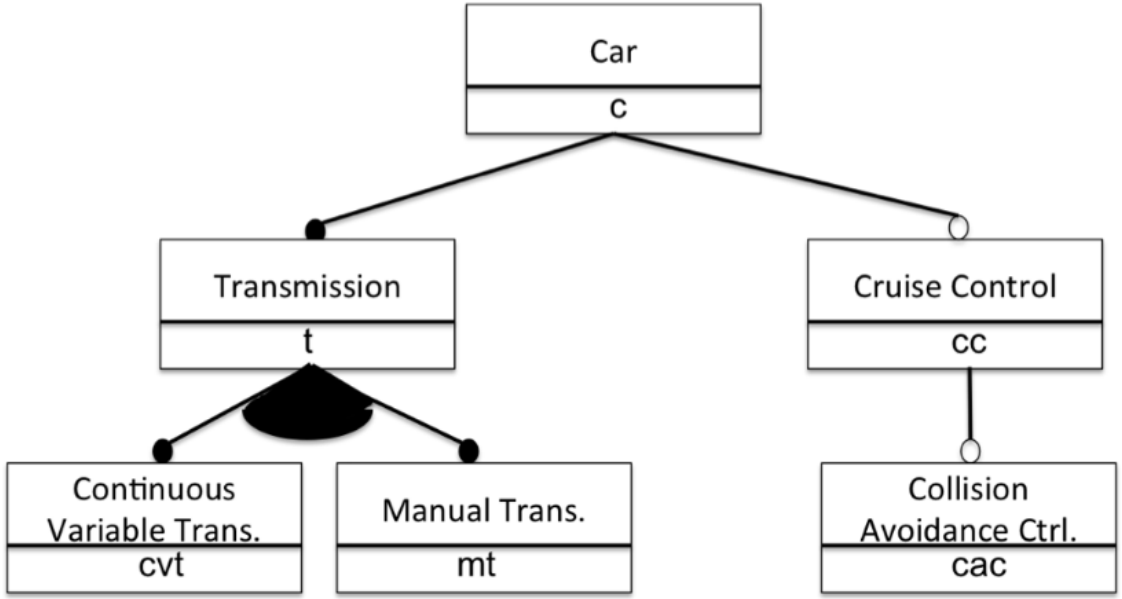
- Semantic notion of **coverage**
  (preserved by behavioral equivalence)
  See: [M. Volpato and J. Tretmans JAMAICA'13]

Other Open Problems

- IOCO for **hybrid** (cyber-physical) systems
  See:
  [M. van Osch FATES'06]
  [H. Abbas et el. ICPS'14]

- From **finite tests** (extensional)
  to **proofs** (intensional)
  See:
  [A. de Silva Simao and A. Petrenko MBT'14]
  [W.-L. Huang and J. Peleska ICST'14]

Conformance for Software Product Lines



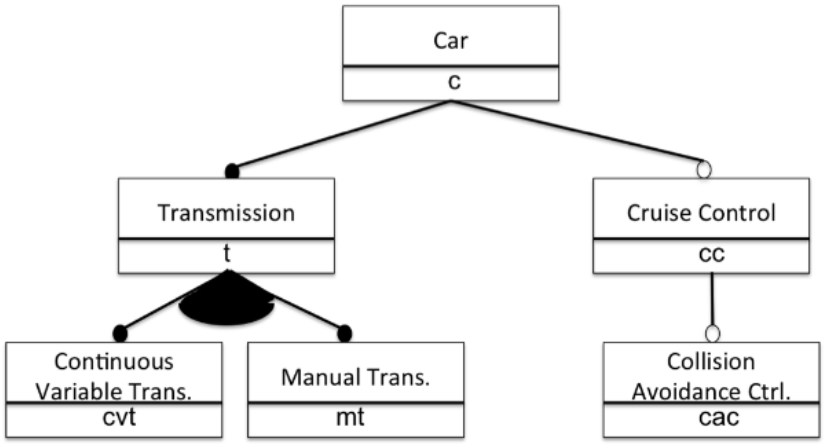
Models for SPLs

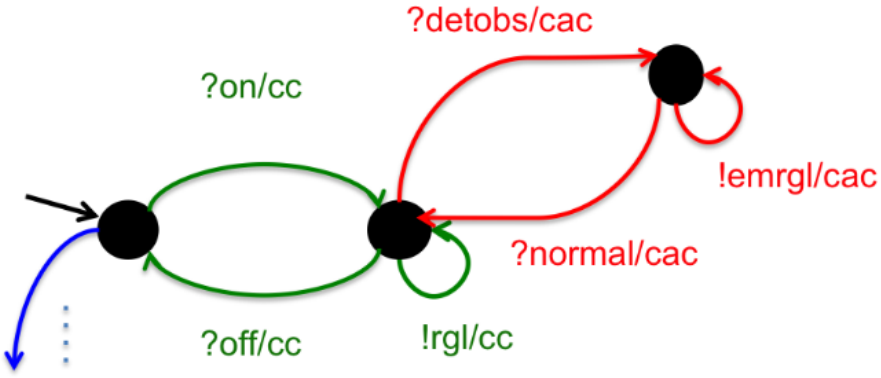
- Various extensions of LTSs:
  Modal- and **Featured Transitions Systems**
- Feature(d) Petri Nets
- PL-CCS
- **Delta-Oriented** FSMs

Featured Input-Output Transition Systems

$(S, s, A_\tau, F, T, \Lambda)$, where:

- S, s, A_τ have the same intuition as in IOLTS,
- F is a set of propositions (features),
- $T \subseteq S \times A_\tau \times \mathbb{B}(F) \times S$
- $\Lambda \subseteq \{\lambda : F \to \mathbb{B}\}$

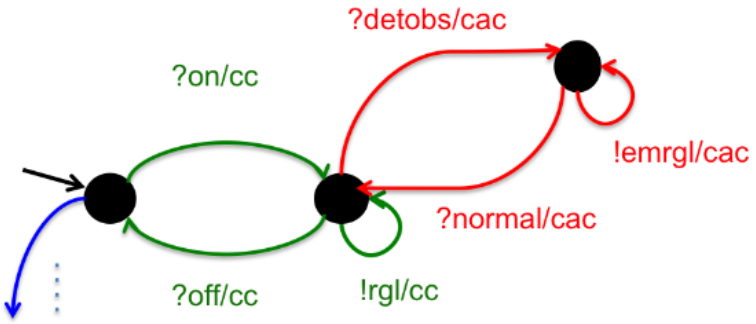


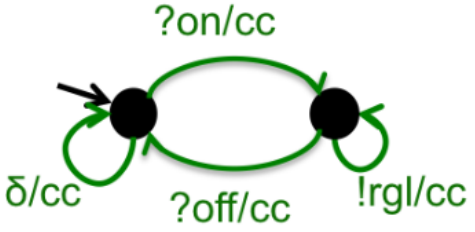


Product Derivation

$$\frac{\exists_\lambda\ \lambda \models (\gamma(s,a,s') \wedge \varphi)}{\Delta_\varphi(s) \xrightarrow{a}_{\gamma(s,a,s')\wedge\varphi} \Delta_\varphi(s')} \quad (1)$$

$$\frac{\nexists_{\lambda,s',a}\ \lambda \models (\gamma(s,a,s') \wedge \varphi) \wedge a \in A_\mathcal{O} \cup \{\tau\}}{\Delta_\varphi(s) \xrightarrow{\delta}_\varphi \Delta_\varphi(s)} \quad (2)$$

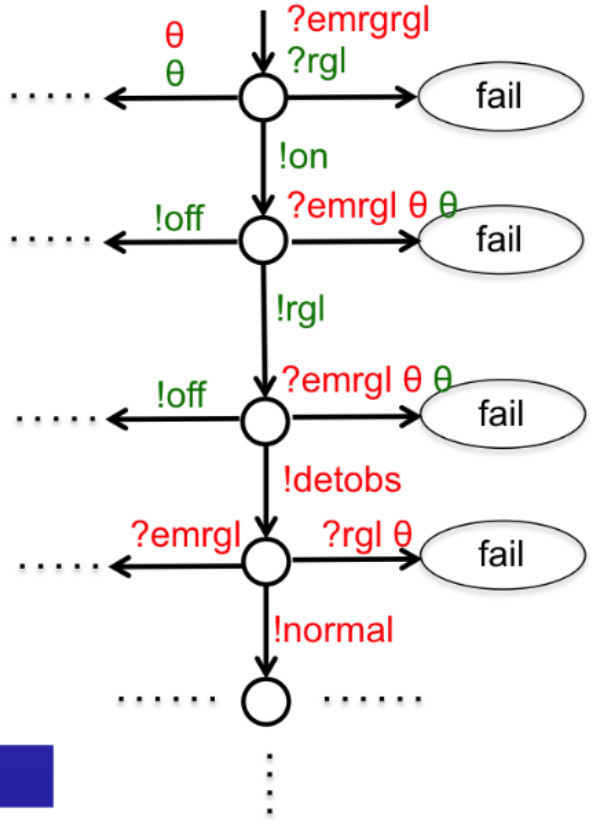


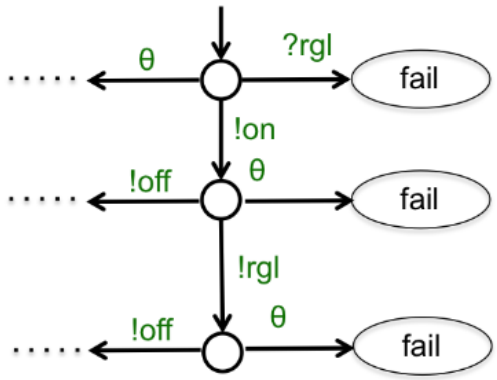


Test-Suite Derivation

$$\frac{X, Y \neq \emptyset \quad (X,\sigma), (Y,\sigma a) \in \mathbf{X}_s^{\varphi}}{(X,\sigma) \xrightarrow{f(a)}_{\varphi} (Y,\sigma a)} \quad (3) \quad \frac{a \in A_{\mathcal{O}} \cup \{\theta\} \quad (X,\sigma) \xrightarrow{a}_{\varphi} (Y,\sigma')}{(X,\sigma) \xrightarrow{a}_{\varphi} \mathbf{pass}} \quad (4)$$

$$\frac{(X,\sigma) \not\xrightarrow{a}_{\varphi} \mathbf{pass}}{(X,\sigma) \xrightarrow{a}_{\varphi} \mathbf{fail}} \quad (5) \quad \frac{a \in A_{\mathcal{O}} \cup \{\theta\}}{\begin{array}{c}\mathbf{pass} \xrightarrow{a}_{\varphi} \mathbf{pass} \\ \mathbf{fail} \xrightarrow{a}_{\varphi} \mathbf{fail}\end{array}} \quad (6)$$

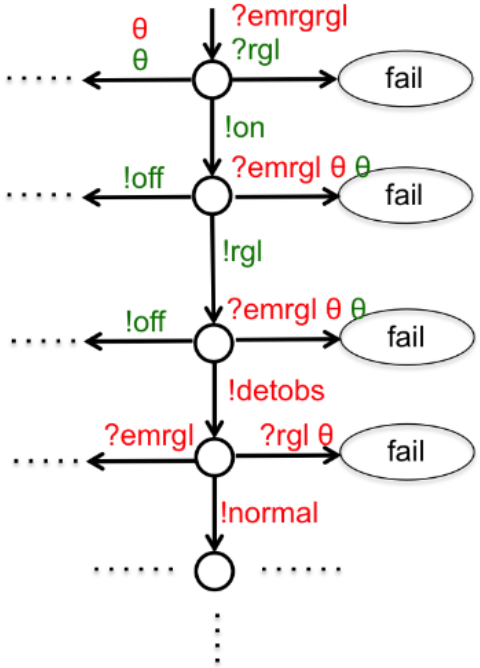


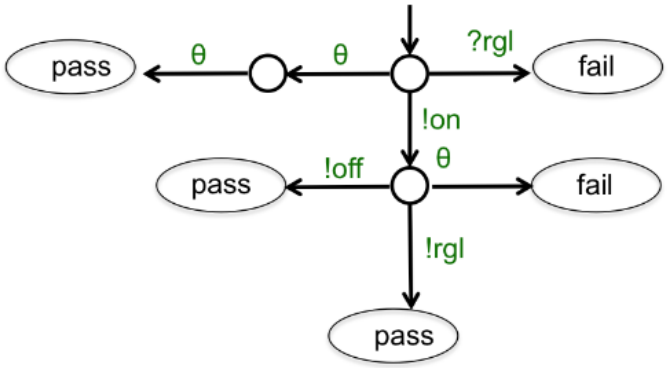


From Test-Suite to Test-Cases

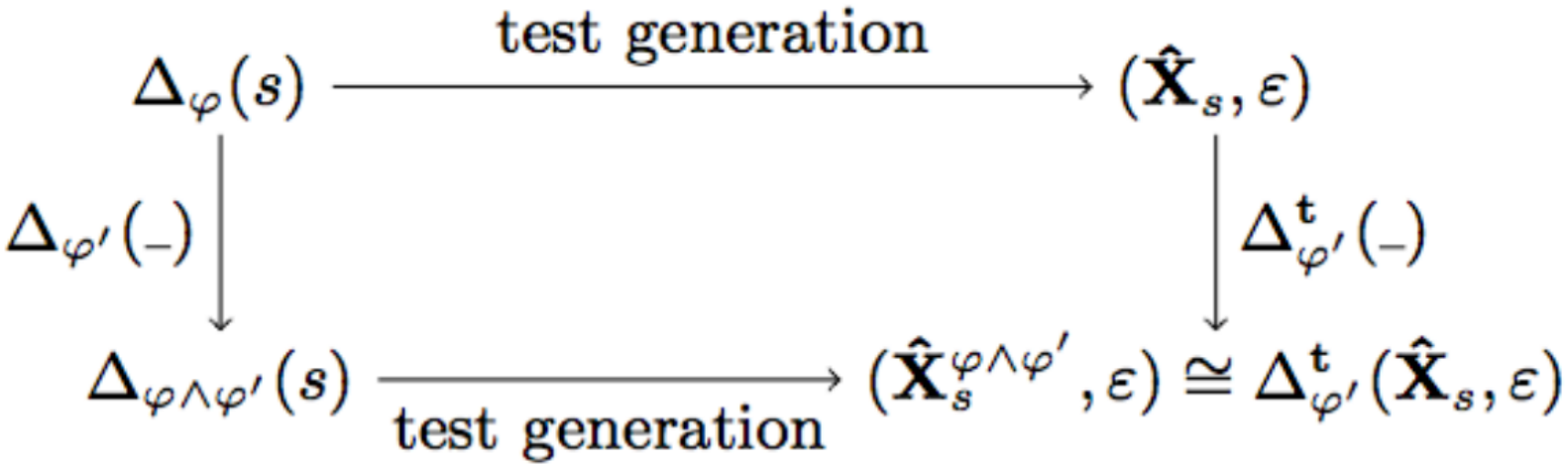
$$\frac{(X,\sigma) \xrightarrow{a}_{\varphi} (Y,\sigma') \wedge |\sigma'| < n}{t_n(X,\sigma) \xrightarrow{a}_{\varphi} t_n(Y,\sigma')} \quad (7)$$

$$\frac{(X,\sigma) \xrightarrow{a}_{\varphi} \mathcal{Y} \wedge (\mathcal{Y} = \mathbf{pass} \vee \mathcal{Y} = \mathbf{fail})}{t_n(X,\sigma) \xrightarrow{a}_{\varphi} \mathcal{Y}} \quad (8)$$





Click!



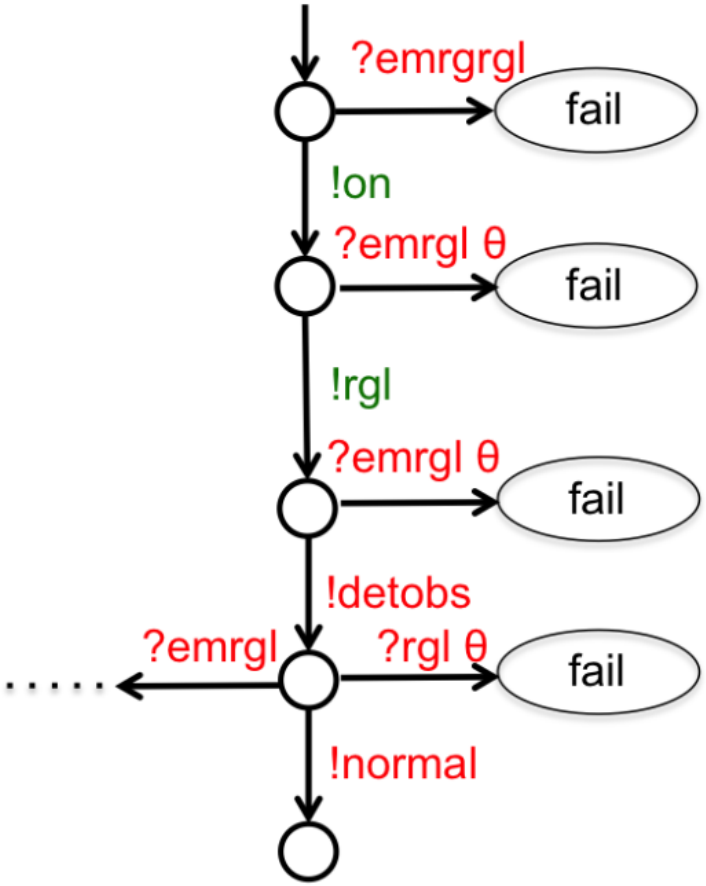
H. Beohar and M.R. Mousavi. Input-Ouput Conformance Testing Based on Feature Transition Systems, ACM SAC-SVT 2014.

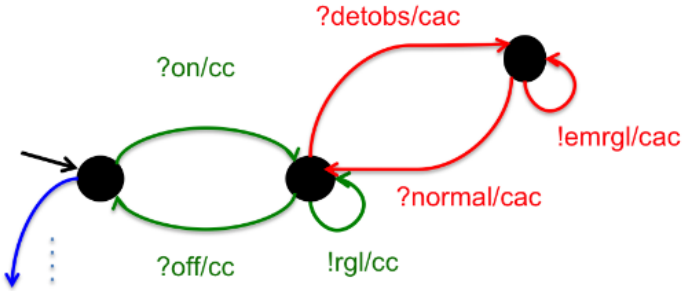
Why Bother?

A test process such that:

- The behavior of **every relevant feature** is **covered**, and
- testing the whole product **less time/effort** than testing **the individual products**.

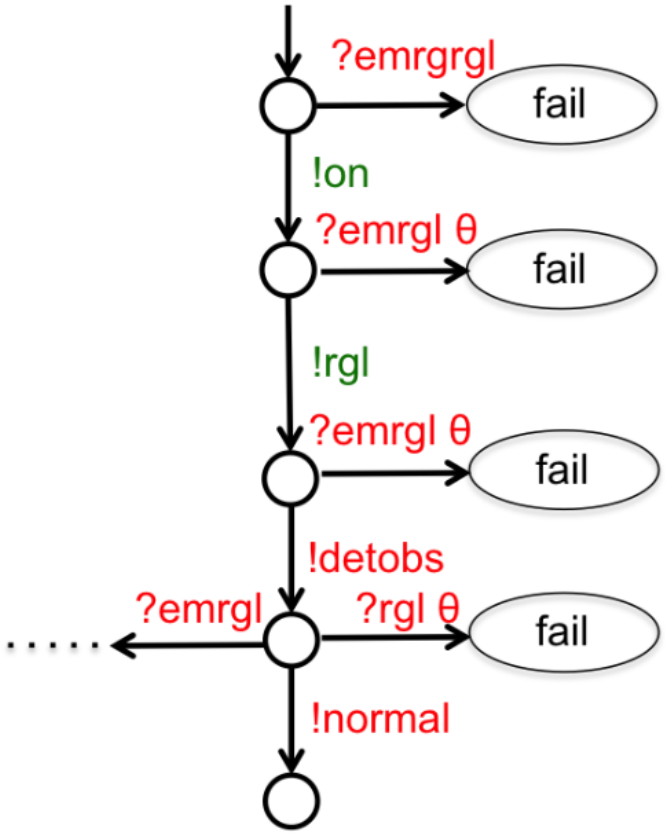
Spinal Test Suites

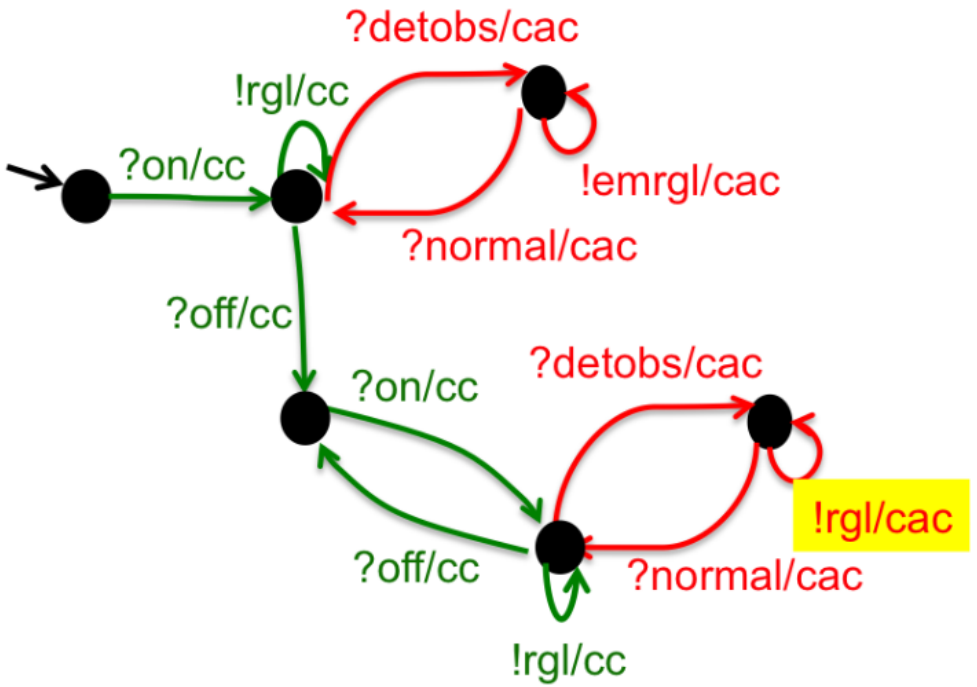




Spines: Simple paths through test suite leading to new behavior

Non-Exhaustiveness





Recovering Exhaustiveness

Orthogonal implementations:

old features do not turn new features on/off at will

Theorem: Spinal test suites are exhaustive for orthogonal implementations

H. Beohar and M.R. Mousavi. Spinal Conformance Testing for Software Product Lines. MBT 2014.

Ongoing Research
Open Issues

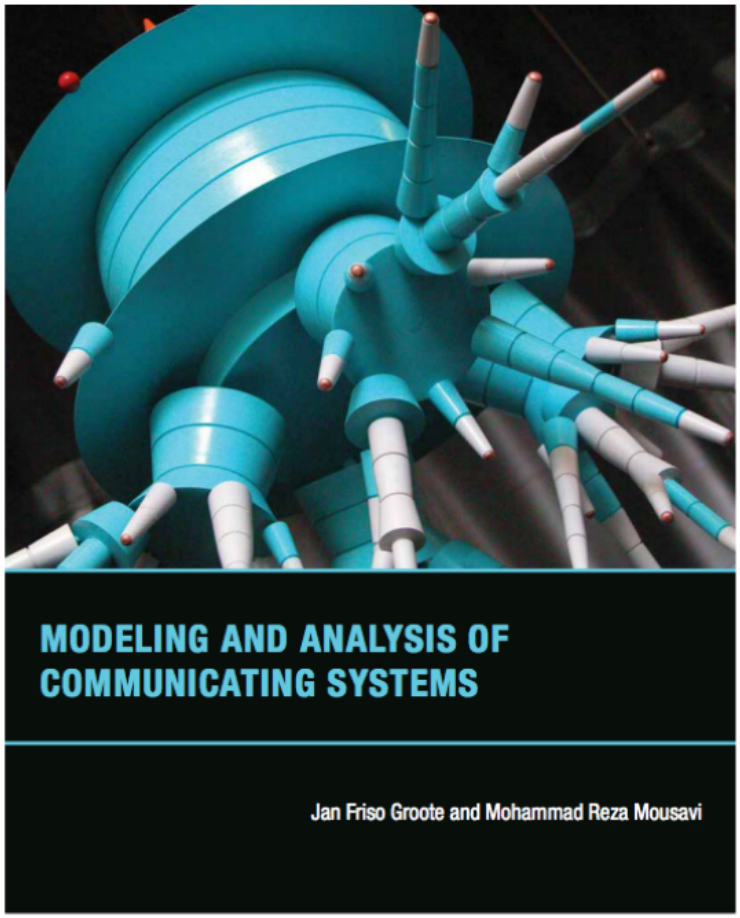
Making This Work

- Defining spinal test suite generation as a reachability problem
- Implementation
  (in a model-checking framework)
- Application to practical case-studies:
  Healthcare application product line (Phoniro),
  AUTOSAR standard (QuviQ)

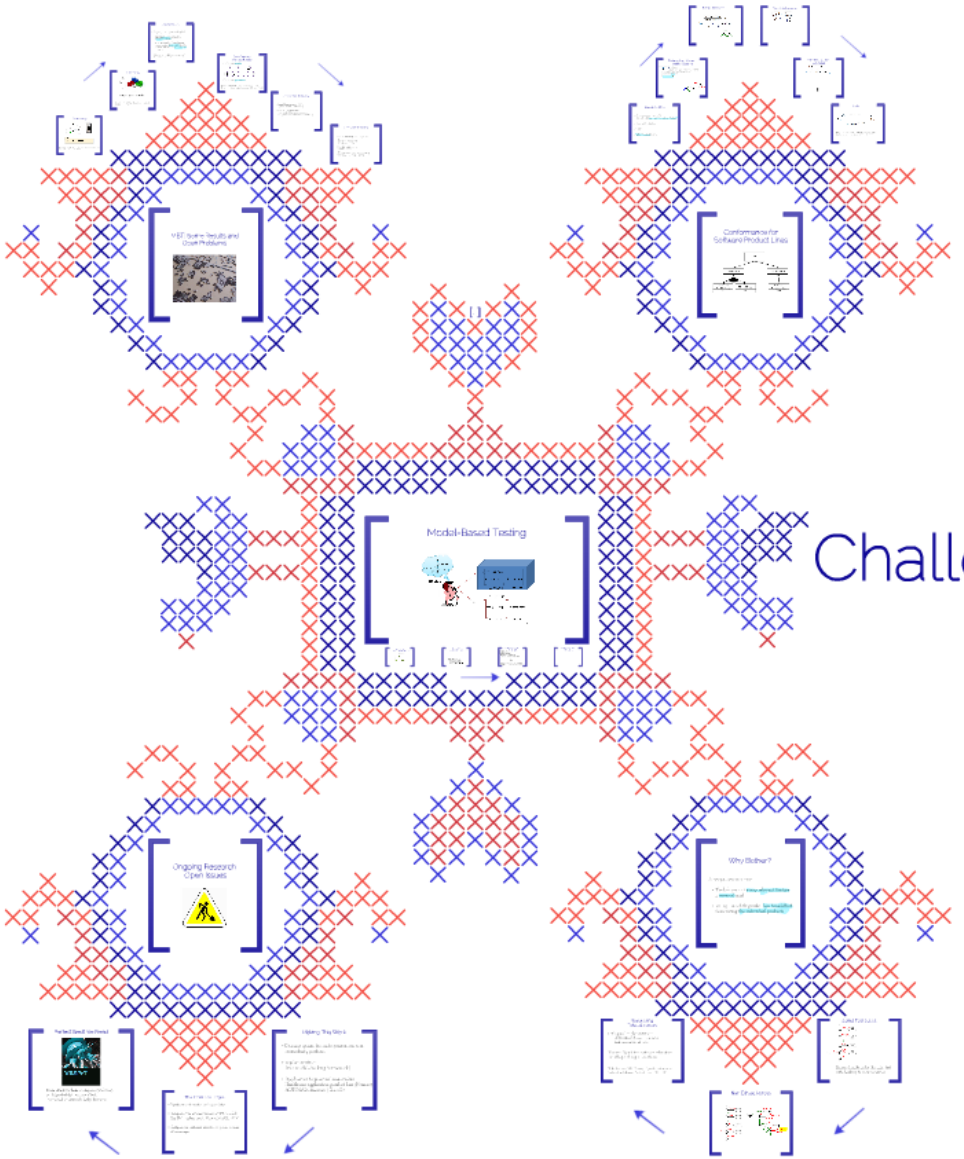
Theoretical Challenges

- Syntactic criteria for orthogonality
- Comparative expressiveness of SPL models
  See: [M. Lochau and J. Kamischke ISoLA'12]
- Comparing test-case sizes for a given notion of coverage

Perfect Bedtime Read



More effective than Diazepam (Valium),
with (probably) less side-effect,
not tested on animals (only humans)



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Thank You!

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