Variability Modules for ABS — @ ABS 2021

(see "Variability Modules for Java-like Languages" @ SPLC 2021)

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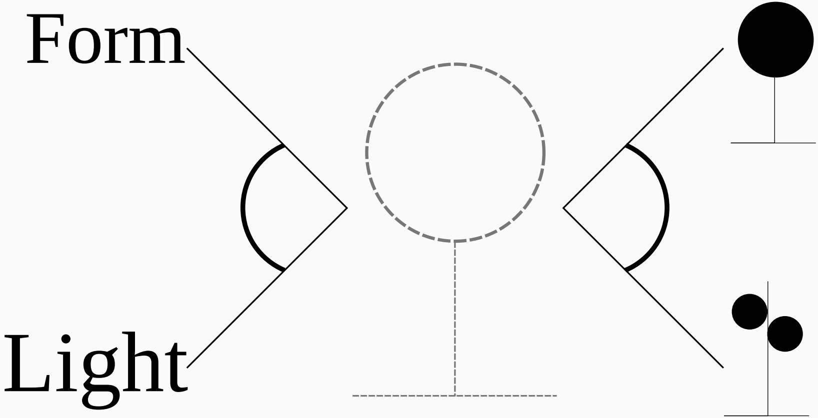
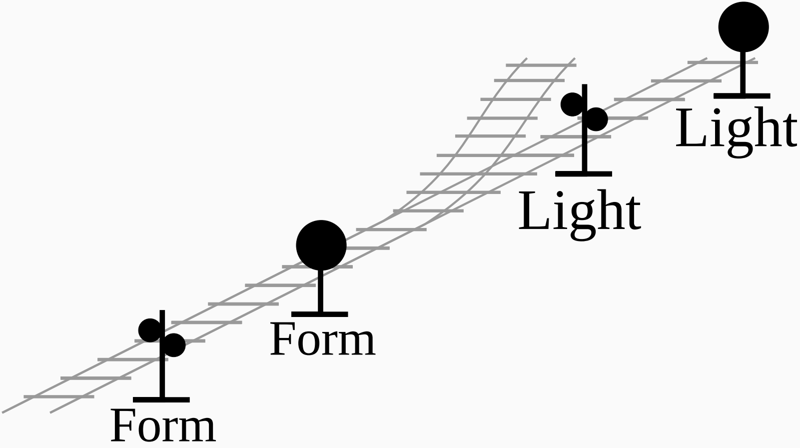
A Product Line for Railway Signals



A Multi-Product Line for Railway Stations (involving Signals, Switches,...)



Interoperable Variants

Challenges

- **Interoperability:** Multiple variants from one PL must coexist and be interoperable: each variant is *encapsulated* and multiple variants *share common code* and may depend on each other.
- **Checkable:** Dependencies between multiple PLs and their variants must be easily trackable.
- **Naturalness:** The mechanism must be natural to the user.

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Variability Modules

Adopt the *module* mechanism to structure the variability and manage dependencies.

Modules, Delta- and Object-Oriented Programming in ABS without VMs

Modules

```
module M;
export I;
import * from M2;

interface I { I m(); }
class C implements I { I m() { return new C(); } }
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Modules

Modules introduce an encapsulated scope for classes and interfaces

- Classes and interfaces may be exported and imported.
- References can be unqualified (`I`) or qualified (`M.I`, `M2.I`)

Variability

Delta-Oriented Programming

Variability in ABS is based on deltas and features:

- Deltas are sets of modifications of classes and interfaces
- Features are restricted by a feature model
- Each delta is activated by a propositional formula over features
- A set of features is a *configuration*
- A set of features adhering to the feature model is a *product*

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```
features Light, Form, Dir with Light <-> !Form;
delta LDelta;
adds class Signals.CBulb { };
modifies class Signals.CSig { Unit addBulb() { new CBulb();} };
delta LDelta when Light;
```

Variability Modules (VMs) — they can be added on top of any Java-like language

Variability Modules

Variability Modules (VMs)

A VM is a module with a variability model local to its elements.

- Each delta can only modify elements within its module
- Two VMs cannot share features

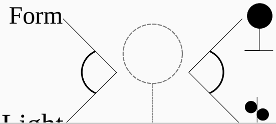
Non-variable elements must be annotated with the `unique` modifier.

Referencing Variants

To reference a variant of a non-`unique` element in a VM, the reference must be annotated with the product.

```
product P = { F2 };
I v = new C() with { F1 };
v = new C() with P;
v = new C() with P + { F1 };
```

Example




```
// MODULE HEADER
module Signals; export LSig, CSig, ISig;
features Light, Form, Dir with Light <-> !Form;
product LSig = {Light};

// CORE PART
unique interface ISig { Bool eqAspect(ISig); Unit setToHalt(); }
class CSig implements ISig { }

// DELTA PART
delta LDelta;
  adds class CBulb { };
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delta FDelta; modifies class CSig { };
...
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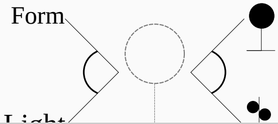


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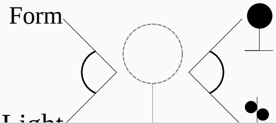


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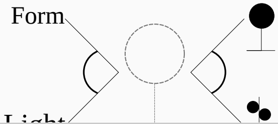


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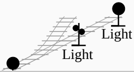


```
// MODULE HEADER
module InterlockingSys; import * from Signals; import * from Switches;
features Modern, DirOut with True;

product PS for Switches = { Modern => {Electric}, !Modern => {Mechanic} }
...

// CORE PART
unique interface IILS { }
class CILS {
 Bool testSig() {
     ...
  ISig sigNormal  = new CSig() with LSig;
  ISig sigShunt   = new CSig() with {Form};
  return sigNormal.eqAspect(sigShunt);
 }
 ISwitch createSwitch() { return new CSwitch() with PS; }
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}
```

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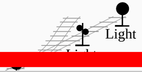


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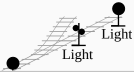


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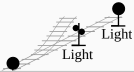


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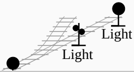


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Flattening

Flattening

A program with VMs can be syntactically flattened into a program without VMs. Further compilation steps are performed on the flattened program.

- While there are references to VM `M` with product `P` on `E`
  1. If a module `M_P` exists, go to 6.
  2. Make a copy `M_P` of `M`
  3. Delete all `unique` elements from `M_P`
  4. Add import clause for `M`
  5. Apply deltas according to `P` to `M_P`
  6. Replace reference with qualified name `M_P.E`
  7. Adapt import clause of dependent module
- For each VM `M`, delete all non-`unique` elements.
- Delete all product declarations and deltas

Example

```
module Signals;
export ISig;
interface ISig { Bool eqAspect(ISig); Unit setToHalt(); }

module Signals_Light;
import * from Signals; export CSig;
class CSig implements ISig { Unit addBulb() { new CBulb();} }
class CBulb { };

module InterlockingSys;
import * from Signals; import * from Signals_Light;
...

class CILS {
 Bool testSig() {
     ...
  ISig sigNormal  = new Signals_Light.CSig();
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```

Principle of Encapsulated Variability

Definition: Principle of Encapsulated Variability (PEV)

A module depends on other variable modules only via `unique` elements or elements with a specified variant.

Checking Uniqueness

Each unique element can only depend on `unique` elements or elements with a specified variant *within its own module*.
A delta can only modify non-`unique` classes.

Theorem

If a program adheres to the PEV and all the delta-applications in each VM succeed, then flattening succeeds.

Examples

Invalid dependency on M.D

```
module M; features ...;

class D implements I {}
...

module N;
...
class E { Unit m() { ... new D(); } }
```

Invalid internal reference on

```
module M;
...
unique interface I {}
unique class C { I m(){ return new D(); }}
class D implements I {}
...
delta Del;
modifies class D;
```

Discussion and Evaluation

Discussion

Implementation

Implementation for ABS available at
https://github.com/abstools/abstools/tree/local_productlines

- Framework and PEV not specific for ABS
- Far more usable than prior approach to interoperability
  - Extends concepts natural to the programmer
  - Introduces no new scopes
- Not discussed here: formal semantics, open product declarations, exact handling of import/export clauses

Evaluation

Case Study 1 (AISCO): AVS-VM vs. External Tool Chain

- Modular web portal using ABS for variability of modules.
- Used an external tool chain to implement interoperability, could be re-implemented completely using AVS-VM.

Case Study 2 (Railway Operations): AVS-VM vs. Traits

ABS model of railway operations of Deutsche Bahn. Infrastructure used object-orientation and traits for interoperable variability.

- Using AVS-VM made implicit constraints (certain traits cannot be used together) explicit in the feature model.
- -25% LoC for relevant infrastructure modeling

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Extend ABS model of weak memory models to handle an architecture with 4 different memory models

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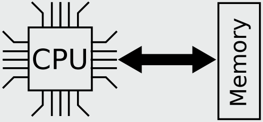

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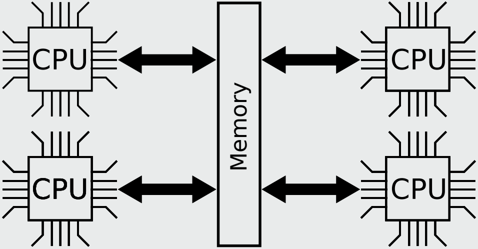

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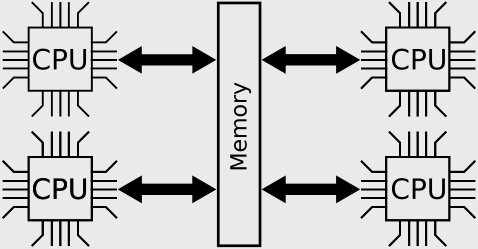
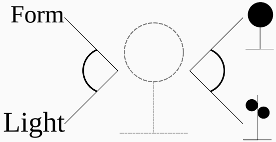
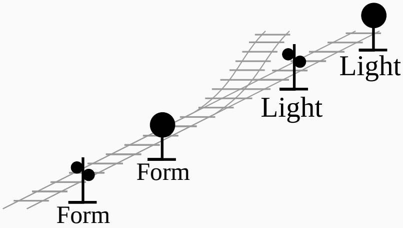


- Naïve approach: copy variability, then refactor common part
- AVS-VM: -63% LoC, scales for any number of memory models

Conclusion

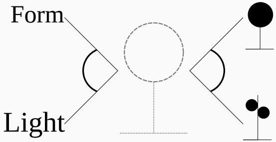


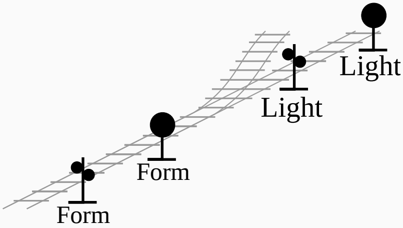


Summary

- Modules as units of variability
- Encapsulated variability for interoperable variants
- On-Going Work: Family-Based Type Checking

Conclusion





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- On-Going Work: Family-Based Type Checking

Thanks you for your attention!