DSL Design

A conceptual framework for building good DSLs

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Introduction

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A DSL is a **focussed**, **processable language** for describing a specific **concern** when building a system in a specific **domain**. The **abstractions** and **notations** used are natural/suitable for the **stakeholders** who specify that particular concern.

Concepts (abstract syntax)

(concrete) Syntax

semantics (generators)

Tools and IDE

	more in GPLs	more in DSL
Domain Size	large and complex	smaller and well-defined
Designed by	guru or committee	a few engineers and domain experts
Language Size	large	small
Turing-completeness	almost always	often not
User Community	large, anonymous and widespread	small, accessible and local
In-language abstraction	sophisticated	limited
Lifespan	years to decades	months to years (driven by context)
Evolution	slow, often standardized	fast-paced
Incompatible Changes	almost impossible	feasible

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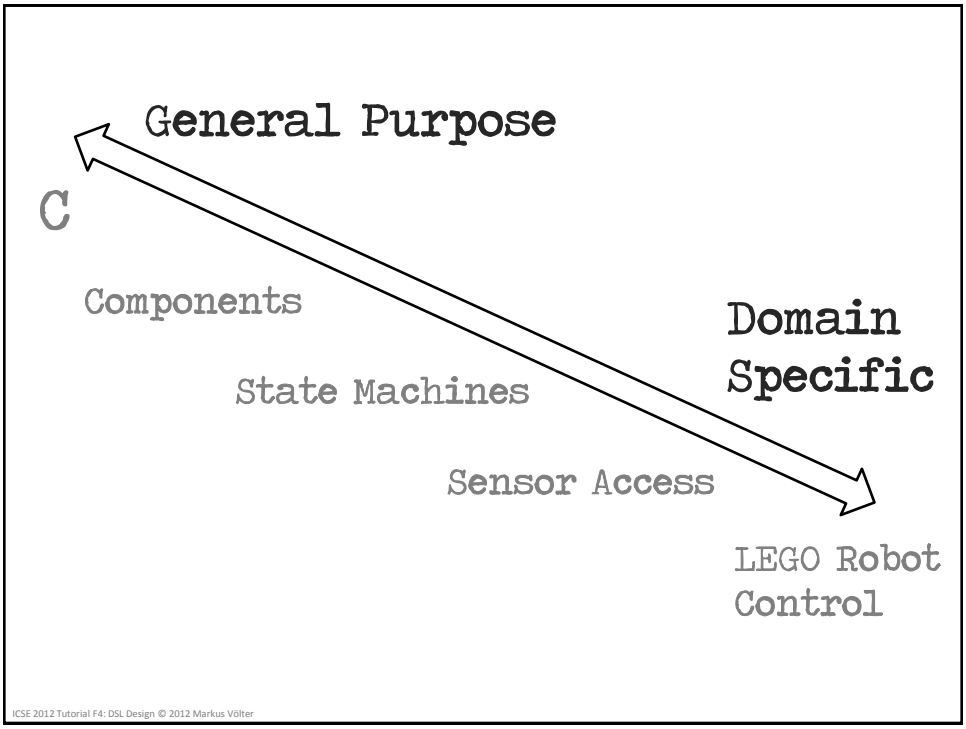

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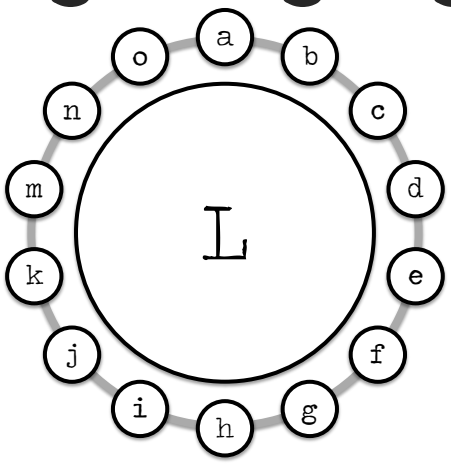
Big Language



with **many** first class concepts!

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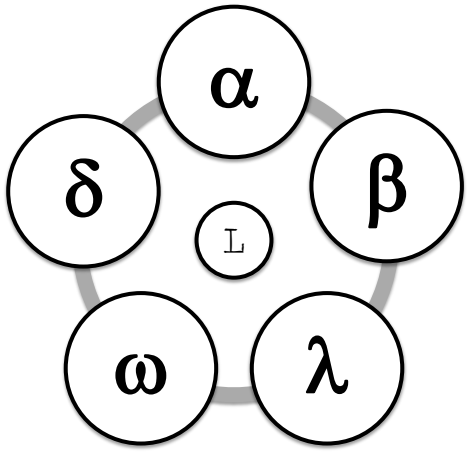
Small Language



with a **few, orthogonal** and **poweful** concepts

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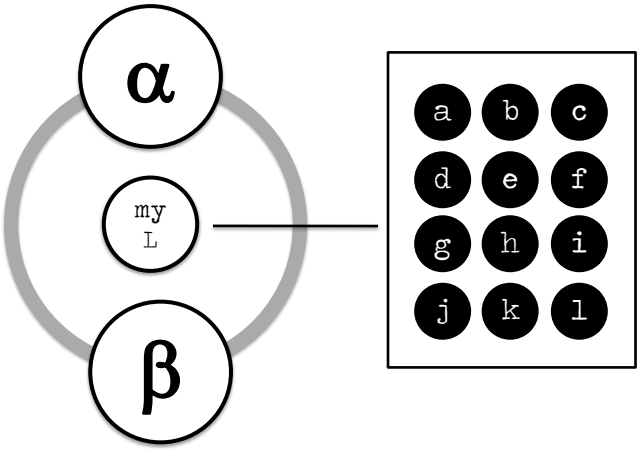
Modular Language



with many optional, composable modules

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Case Studies

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```
namespace com.mycompany {
  namespace datacenter {
    component DelayCalculator {
      provides aircraft: IAircraftStatus
      provides console: IManagementConsole
      requires screens[0..n]: IInfoScreen
    }
    component Manager {
      requires backend[1]: IManagementConsole
    }
    public interface IInfoScreen {
      message expectedAircraftArrivalUpdate
              (id: ID, time: Time)
      message flightCancelled(flightID: ID)
    }
    public interface IAircraftStatus …
    public interface IManagementConsole …
  }
}
```

Example

Components


```
namespace com.mycompany.test {
  system testSystem {
    instance dc: DelayCalculator
    instance screen1: InfoScreen
    instance screen2: InfoScreen
    connect dc.screens to
      (screen1.default, screen2.default)
  }
}
```

Example

Components

```
appliance KIR {

    compressor compartment cc {
        static compressor c1
        fan ccfan
    }

    ambient tempsensor at

    cooling compartment RC {
        light rclight
        superCoolingMode
        door rcdoor
        fan rcfan
        evaporator tempsensor rceva
    }

}
```

Example

Refrigerators


```
parameter t_abtaustart: int
parameter t_abtaudauer: int
parameter T_abtauEnde: int

var tuerNachlaufSchwelle: int = 0

start:
    entry { state noCooling }

state noCooling:
    check ( (RC->needsCooling) && (cc.c1->stehzeit > 333) ) {
        state rccooling
    }
    on isDown ( RC.rcdoor->open ) {
        set RC.rcfan->active = true
        set RC.rclight->active = false
        perform rcfanabschalttask after 10 {
            set RC.rcfan->active = false
        }
    }


state rccooling:
    entry { set RC.rcfan->active = true }
    check ( !(RC->needsCooling)  ) {
        state noCooling
    }
    on isDown ( RC.rcdoor->open ) {
        set RC.rcfan->active = true
        set RC.rclight->active = false
        set tuerNachlaufSchwelle = currStep + 30
    }
    exit {
        perform rcfanabschalttask after max( 5, tuerNachlaufSchwelle-currStep ) {
            set RC.rcfan->active = false
        }
    }
```

Example

Refrigerators

```
parameter t_abtaustart: int
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        set tuerNachlaufSchwelle = currStep + 30
    }
    exit {
        perform rcfanabschalttask after max( 5, tuerNachlaufSchwelle-currStep ) {
            set RC.rcfan->active = false
        }
    }
```

```
prolog {
    set RC->accumulatedRuntime = 80
}

step 10
assert-currentstate-is noCooling

mock: set RC->accumulatedRuntime = 110
step


mock: set RC.rceva->evaTemp = 10
assert-currentstate-is abtauen
assert-value cc.c1->active is false
mock: set RC->accumulatedRuntime = 0
step 5
assert-currentstate-is abtauen
assert-value cc.c1->active is false
step 15
assert-currentstate-is noCooling
```

Example

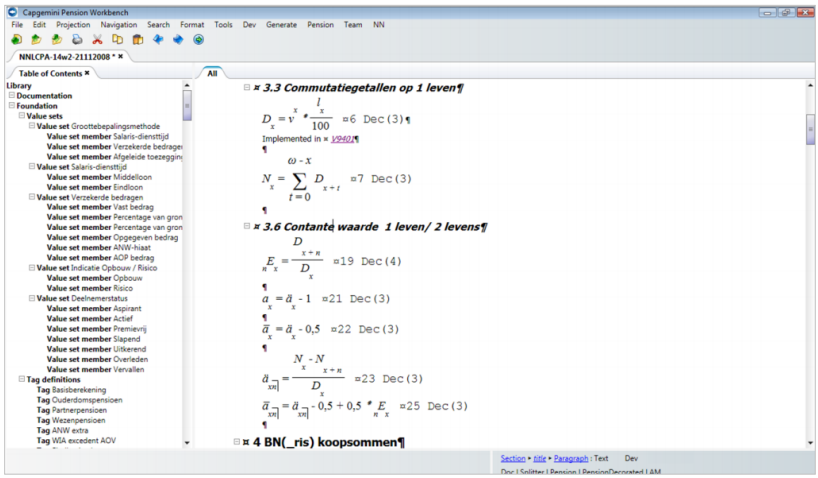
Refrige rators


```
module main imports OsekKernel, EcAPI, BitLevelUtilies {

  constant int WHITE = 500;
  constant int BLACK = 700;
  constant int SLOW = 20;
  constant int FAST = 40;

  statemachine linefollower {
    event initialized;
    initial state initializing {
      initialized [true] -> running
    }
    state running { }
  }

  initialize {
    ecrobot_set_light_sensor_active
                (SENSOR_PORT_T::NXT_PORT_S1);
    event linefollower:initialized
  }

  terminate {
    ecrobot_set_light_sensor_inactive
                (SENSOR_PORT_T::NXT_PORT_S1);
```

```
task run cyclic prio = 1 every = 2 {
  stateswitch linefollower
    state running
      int32 light = 0;
      light = ecrobot_get_light_sensor
                          (SENSOR_PORT_T::NXT_PORT_S1);
      if ( light < ( WHITE + BLACK ) / 2 ) {
        updateMotorSettings(SLOW, FAST);
      } else {
        updateMotorSettings(FAST, SLOW);
      }
    default
      <noop>;
}

void updateMotorSettings( int left, int right ) {
  nxt_motor_set_speed(MOTOR_PORT_T::NXT_PORT_C, left, 1);
  nxt_motor_set_speed(MOTOR_PORT_T::NXT_PORT_B, right, 1);
}
```

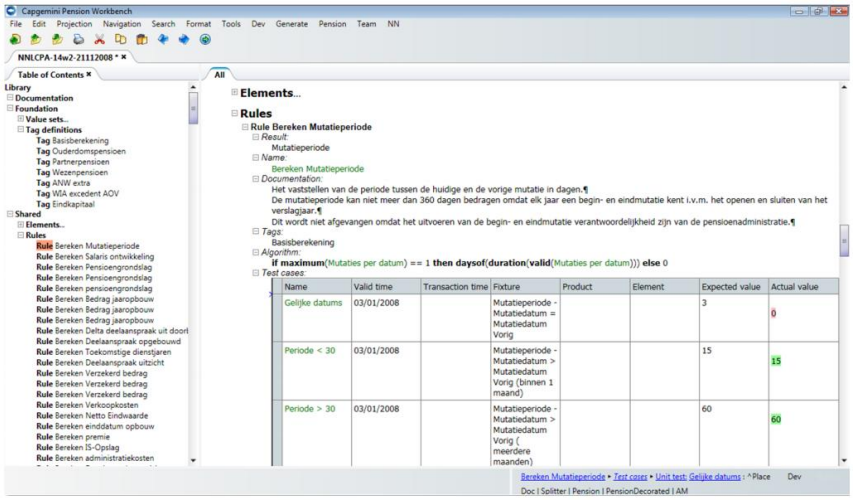
Example

Exten ded C



Example

Pension Plans



Example

Pension Plans

```
entity Post {
  key       :: String (id)
  blog      → Blog
  urlTitle  :: String
  title     :: String (searchable
  content   :: WikiText (searchab
  public    :: Bool (default=fals
  authors   → Set<User>
  function isAuthor(): Bool {
    return principal() in authors
  }
  function mayEdit(): Bool {
    return isAuthor();
  }
  function mayView(): Bool {
    return public || mayEdit();
  }
```

```
access control rules
  rule page post(p: Post, title: String) {
    p.mayView()
  }
  rule template newPost(b: Blog) {
    b.isAuthor()
  }
section posts
  define page post(p: Post, title: String) {
    title{ output(p.title) }
    bloglayout(p.blog){
      placeholder view { postView(p) }
      postComments(p)
    }
  }
  define permalink(p: Post) {
    navigate post(p, p.urlTitle) { elements }
  }
```

Example

Web DSL

Terms & Concepts

Model

A schematic description of a system, theory, or phenomenon that accounts for its known or inferred properties and may be used for further study of its characteristics

www.answers.com/topic/model

Model

A representation of a set of components of a process, system, or subject area, generally developed for understanding, analysis, improvement, and/or replacement of the process

www.ichnet.org/glossary.htm

Model

an abstraction or simplification of reality

ecosurvey.gmu.edu/glossary.htm

Model

which ones?

an abstraction or simplification of reality

what should we leave out?

ecosurvey.gmu.edu/glossary.htm

Model Purpose

… code generation
… analysis and checking
… platform independence
… stakeholder integration
…

drives design of language!

Model Purpose

… code generation
… analysis and checking
… platform independence
… stakeholder integration

Example

Components

Model Purpose

- … code generation
- … analysis and checking
- … platform independence
- … stakeholder integration

Example

Refrige rators

Model Purpose

- … code generation
- … analysis and checking
- … platform independence
- … stakeholder integration

Example

Exten ded C

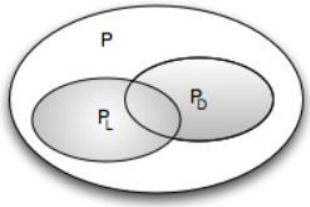
Model Purpose

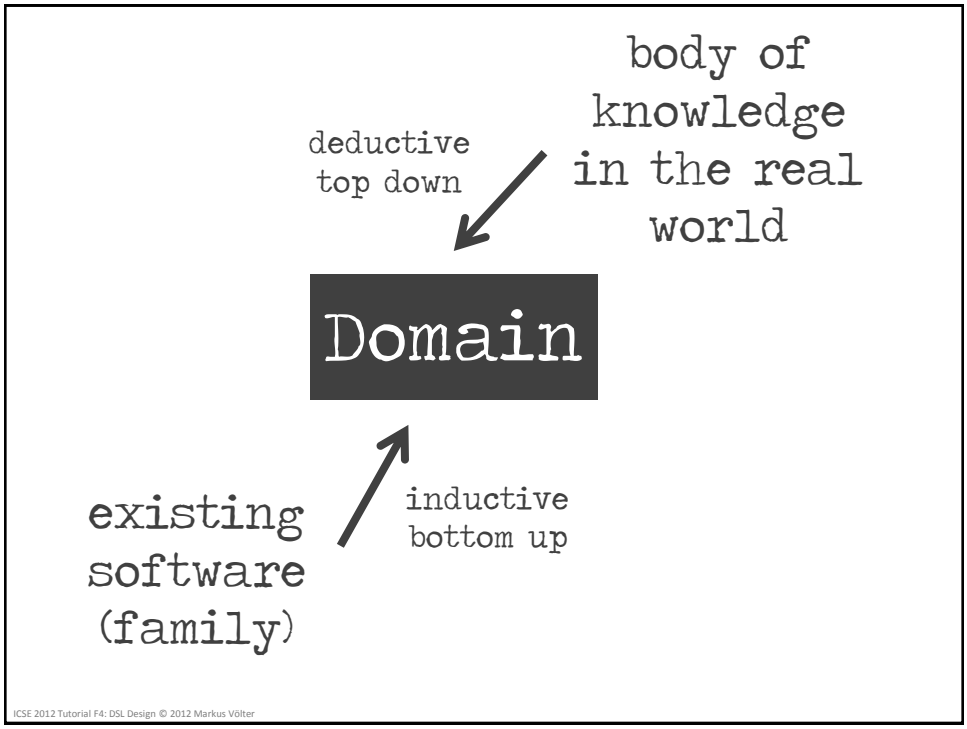
… code generation
… analysis and checking
… platform independence
… stakeholder integration

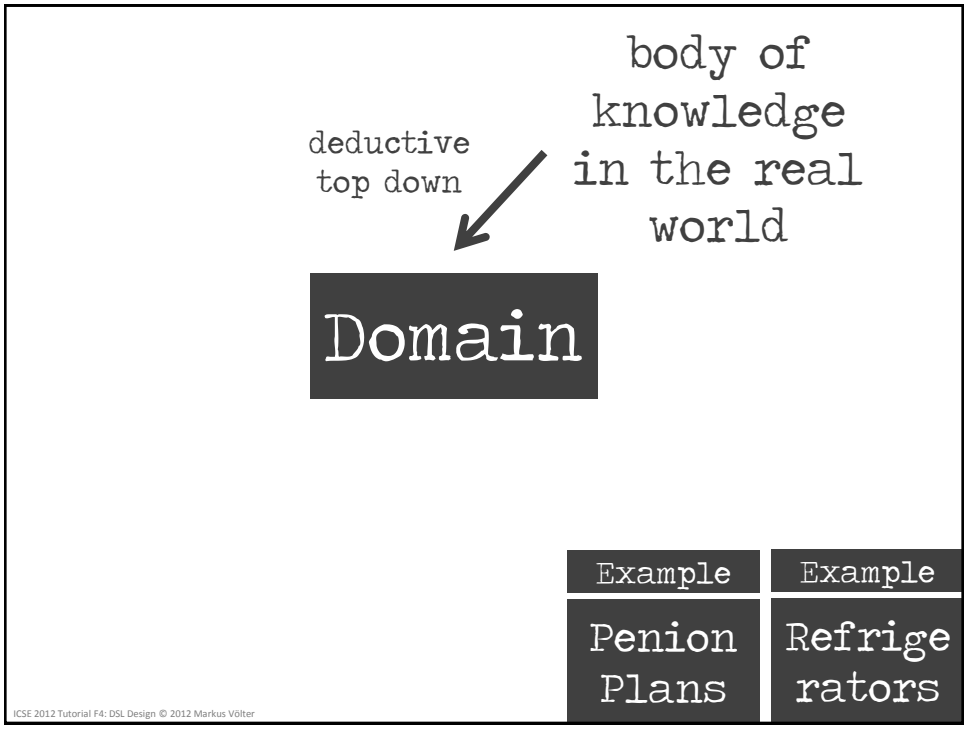
Example

Pension Plans

Programs Languages Domains




body of knowledge in the real world
deductive top down
Domain
existing software (family)
inductive bottom up


body of knowledge in the real world
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Example
Penion Plans
Example
Refrige rators

Domain

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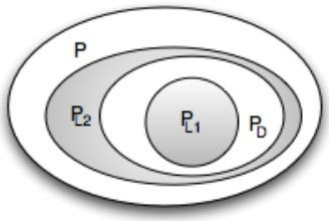
inductive bottom up

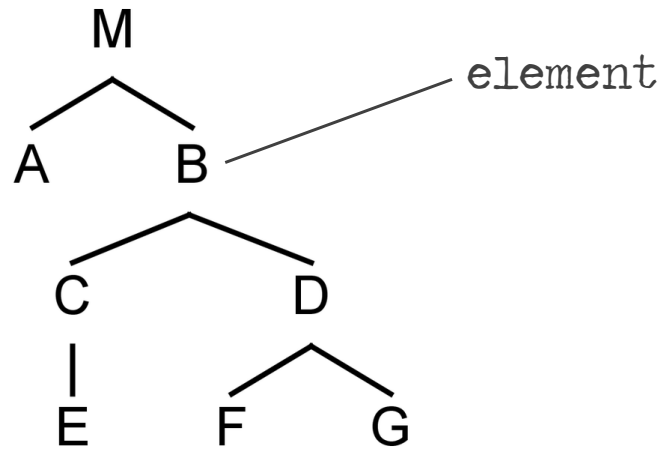
Example	Example
Extended C	Components



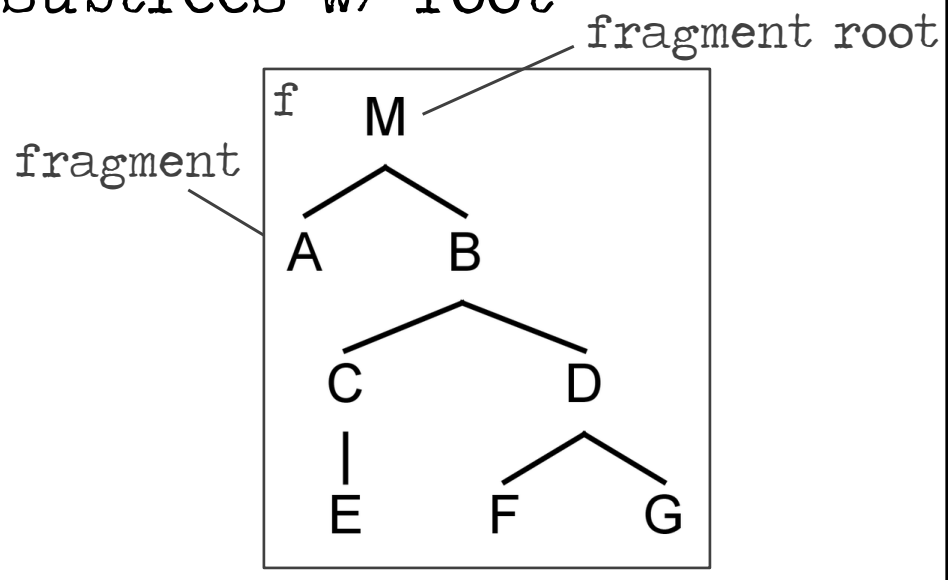
A DSL L_D **for** D **is a language that is specialized** to encoding P_D programs.

more efficient
smaller

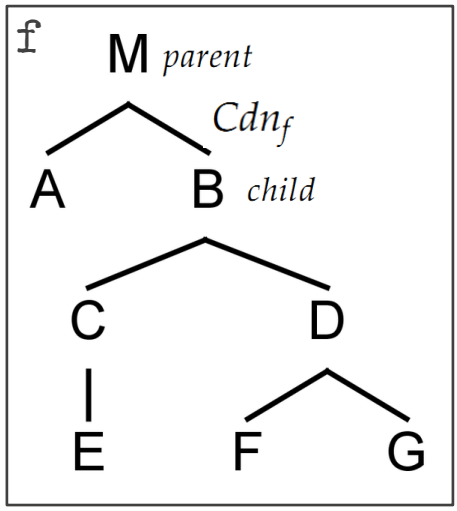
Programs are trees



Fragments are subtrees w/ root



Parent-Child Relation



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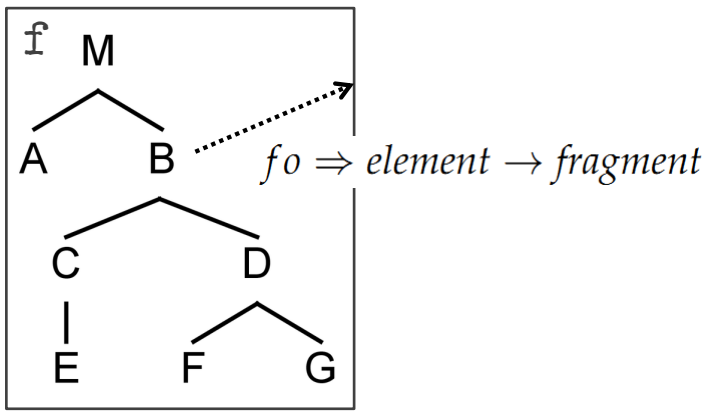
Programs and Fragments



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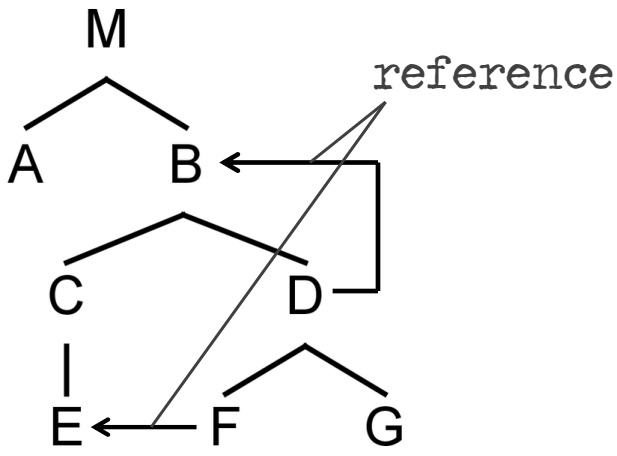
Programs are graphs, really.



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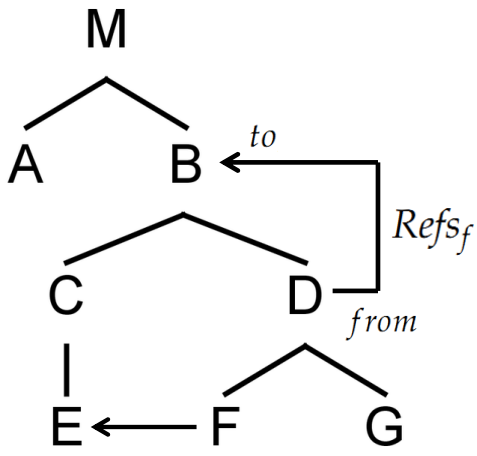
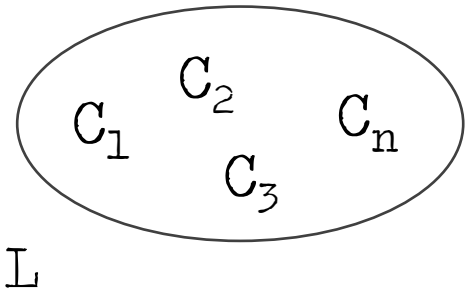
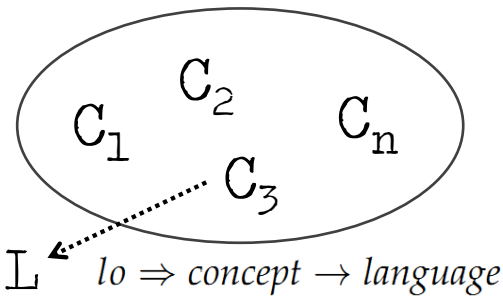


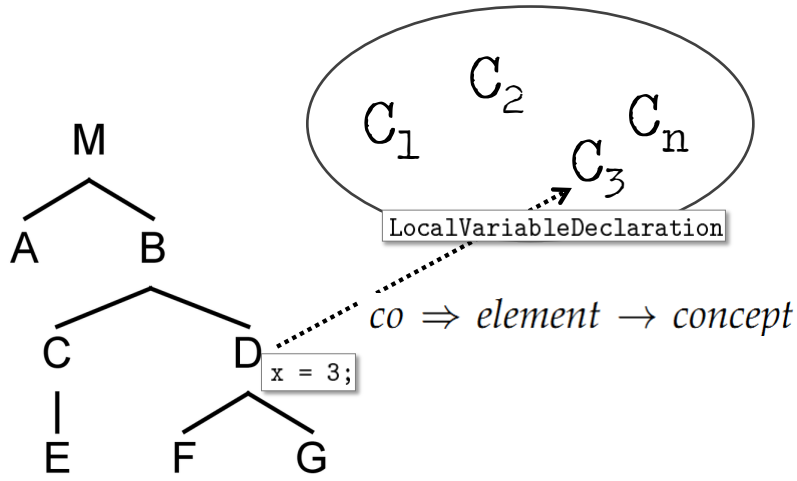
Languages are sets of concepts



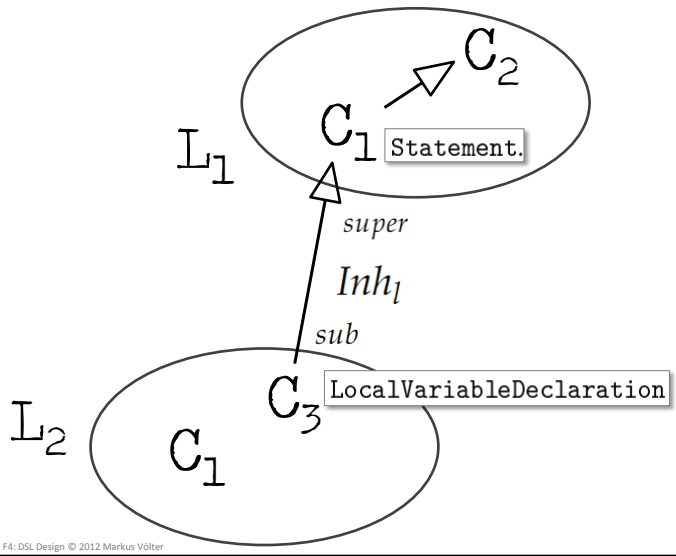
Languages are sets of concepts



Programs and languages



Language: concept inheritance



Language
does not depend on
any other language

$$\forall r \in Refs_l \mid lo(r.to) = lo(r.from) = l$$
$$\forall s \in Inh_l \mid lo(s.super) = lo(s.sub) = l$$
$$\forall c \in Cdn_l \mid lo(c.parent) = lo(c.child) = l$$

Independence

Fragment
does not depend on
any other fragment

$$\forall r \in Refs_f \mid fo(r.to) = fo(r.from) = f$$
$$\forall e \in E_f \mid lo(co(e)) = l$$

Independence

Hardware:

```
compressor compartment cc {
    static compressor c1
    fan ccfan
}
```

Cooling Algorithm

```
macro kompressorAus {
    set cc.c1->active = false
    perform ccfanabschalttask after 10 {
        set cc.ccfan->active = false
    }
}
```

Example

Refrige rators

Homogeneous

Fragment

everything expressed
with one language

$$\forall e \in E_f \mid lo(e) = l$$

$$\forall c \in Cdn_f \mid lo(c.parent) = lo(c.child) = l$$

Heterogeneous

```
module CounterExample from counterd imports nothing {

  var int theI;

  var boolean theB;

  var boolean hasBeenReset;

  statemachine Counter {
    in start() <no binding>
       step(int[0..10] size) <no binding>
    out someEvent(int[0..100] x, boolean b) <no binding>
        resetted() <no binding>
    vars int[0..10] currentVal = 0
         int[0..100] LIMIT = 10
    states (initial = initialState)
      state initialState {
        on start [ ] -> countState { send someEvent(100, true && false || true); }
      }
      state countState {
        on step [currentVal + size > LIMIT] -> initialState { send resetted(); }
        on step [currentVal + size <= LIMIT] -> countState { currentVal = currentVal + size; }
        on start [ ] -> initialState {  }
      }
  } end statemachine

  var Counter c1;

  exported test case test1 {
    initsm(c1);
    assert(0) isInState<c1, initialState>;
    trigger(c1, start);
    assert(1) isInState<c1, countState>;
  } test1(test case)
}
```

Example

Exten
ded C

```
module CounterExample from counterd imports nothing {

  var int theI;

  var boolean theB;

  var boolean hasBeenReset;

  statemachine Counter {
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    out someEvent(int[0..100] x, boolean b) <no binding>
        resetted() <no binding>
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    states (initial = initialState)
      state initialState {
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      }
      state countState {
        on step [currentVal + size > LIMIT] -> initialState { send resetted(); }
        on step [currentVal + size <= LIMIT] -> countState { currentVal = currentVal + size; }
        on start [ ] -> initialState {  }
      }
  } end statemachine

  var Counter c1;

  exported test case test1 {
    initsm(c1);
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    trigger(c1, start);
    assert(1) isInState<c1, countState>;
  } test1(test case)
}
```

Heterogeneous

C

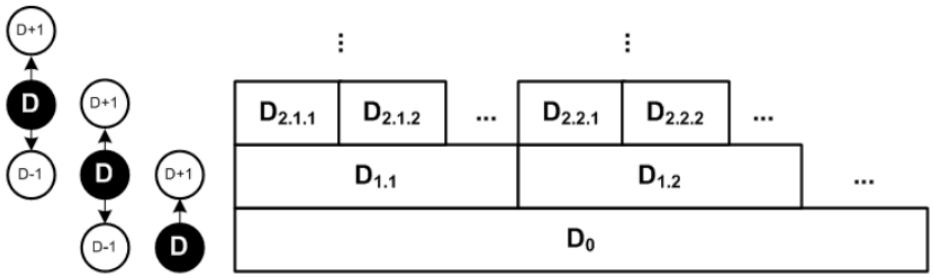
Statemachines

Testing

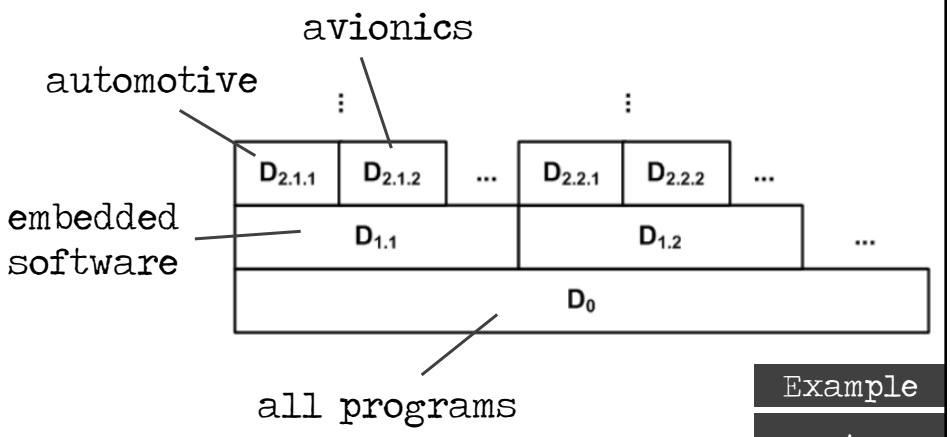
Example

Exten ded C

Domain Hierarchy



Domain Hierarchy



Example

Extended C

Design Dimensions

expressivity	completeness
coverage	paradigms
semantics	modularity
separation of concerns	concrete syntax

process

Expressivity

expressivity	completeness
coverage	paradigms
semantics	modularity
separation of concerns	concrete syntax

process

Shorter Programs

More Accessible Semantics

For a limited Domain!

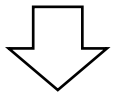
Domain Knowledge encapsulated in language

Def: Expressivity

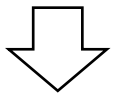
A language L_1 is *more expressive in domain D* than a language L_2

if for each $p \in P_D \cap P_{L_1} \cap P_{L_2}$, $|p_{L_1}| < |p_{L_2}|$

Smaller Domain

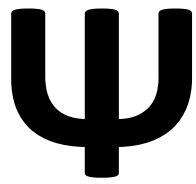


More Specialized Language



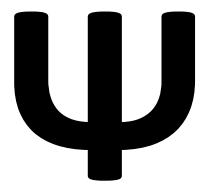
Shorter Programs

The do-what-I-want language

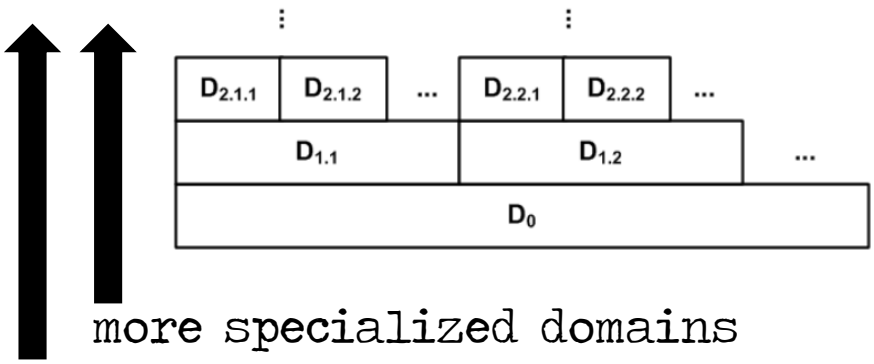


Single Program vs. Class/Domain

No Variability!



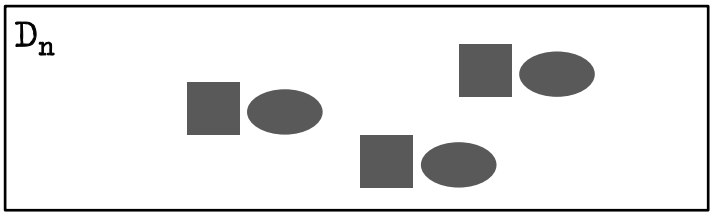
Domain Hierarchy



more specialized domains

more specialized languages

Reification



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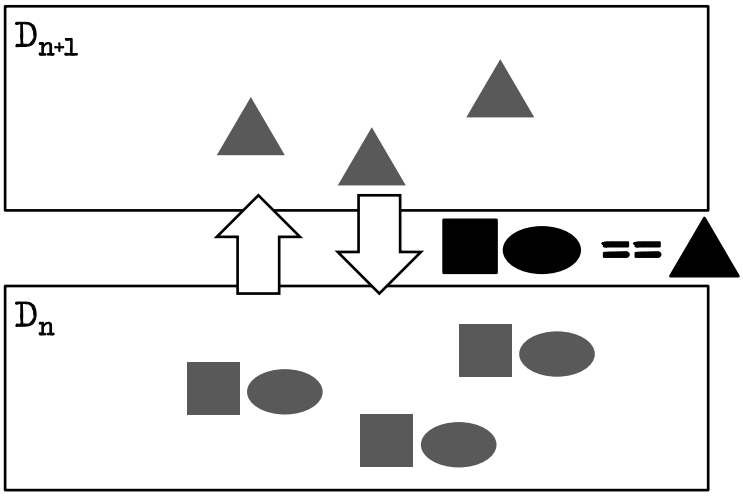
Reification



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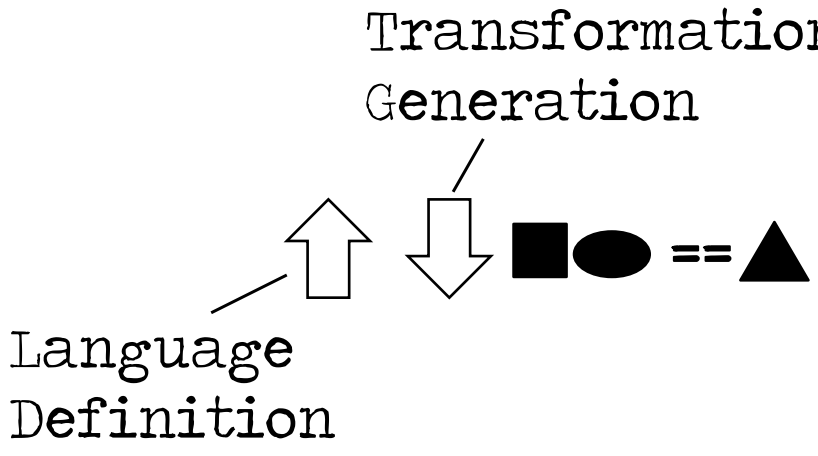
Reification



Overspecification!
Requires Semantic Analysis!

```
int[] arr = ...
for (int i=0; i<arr.size(); i++) {
    sum += arr[i];
}
```

```
int[] arr = ...
List<int> l = ...
for (int i=0;  i<arr.size(); i++) {
    l.add( arr[i] );
}
```

Linguistic Abstraction

```
for (int i in arr) {
    sum += i;
}
```

Declarative!
Directly represents Semantics.

```
seqfor (int i in arr) {
    l.add( arr[i] );
}
```


Def: DSL

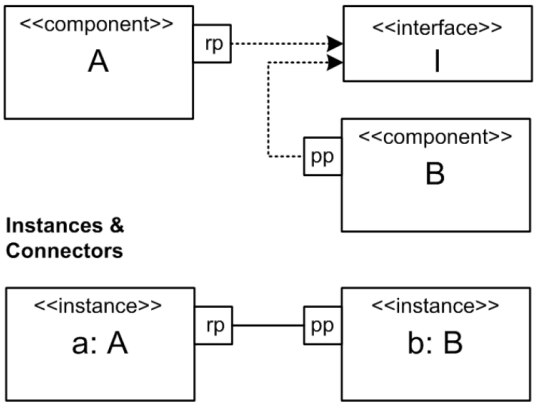
A DSL is a **language** at D that provides **linguistic abstractions** for **common patterns and idioms** of a language at D-1 when used within the domain D.

Def: DSL cont'd

A good DSL does **not** require the use of patterns and idioms to express **semantically interesting** concepts in D. Processing tools do not have to do "semantic recovery" on D programs.

Declarative!

Another Example



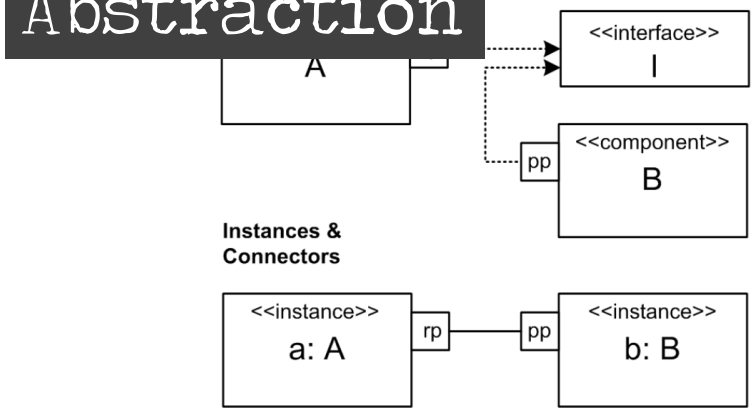

```
if (isConnected(port) || true) {
    port.doSomething();
}
```

Turing Complete!
Requires Semantic Analysis!

Example

Exten
ded C

Linguistic Abstraction




```
with port (port) {
   port.doSomething();
}
```

Example

Extended C

Linguistic Abstraction

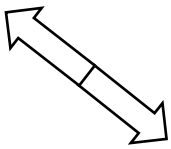
```
exported component AnotherDriver extends Driver {
  ports:
    requires optional ILogger logger
    provides IDriver cmd
  contents:
    field int count = 0

    int setDriverValue(int addr, int value) <- op cmd.setDriverValue {
      with port (logger) {
        logger.log("some error message");
      } with port
      return 0;
    }
}
```

Example

Extended C

Linguistic Abstraction



In-Language Abstraction

Libraries
Classes
Frameworks

Linguistic Abstraction

Analyzable
Better IDE Support

In-Language Abstraction

User-Definable
Simpler Language

Linguistic Abstraction

Analyzable
Better IDE Support

Special Treatment!

In-Language Abstraction

User-Definable
Simpler Language

Linguistic Abstraction

Std Lib

In-Language Abstraction

Std Lib

```
lib stdlib {

    command compartment::coolOn
    command compartment::coolOff
    property compartment::totalRuntime: int readonly
    property compartment::needsCooling: bool readonly
    property compartment::couldUseCooling: bool readonly
    property compartment::targetTemp: int readonly
    property compartment::currentTemp: double readonly
    property compartment::isCooling: bool readonly

}
```

Example

Refrige rators

Language Evolution Support

Customization vs. Configuration

Precision vs. Algorithmics

Coverage

expressivity	completeness
coverage	paradigms
semantics	modularity
separation of concerns	concrete syntax

process

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Domain D_L defined inductively by L

(the domain that can be expressed by L)

$C_L(L) == 1$ (by definition)

not very interesting!

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Def: Coverage

to what extend can a language L cover a domain D

$$C_D(L) = \frac{number\ of\ P_D\ programs\ expressable\ by\ L}{number\ of\ programs\ in\ domain\ D}$$

Def: Coverage

why would $C_D(L)$ be != 1?

1) L is deficient
2) L is intended to cover only a subset of D, corner cases may make L too complex

Rest must be expressed in D_{-1}

Def: Coverage

Coverage is full.
You call always write C.

Example

Exten
ded C

Def: Coverage

Only a particular style of web apps are suported.

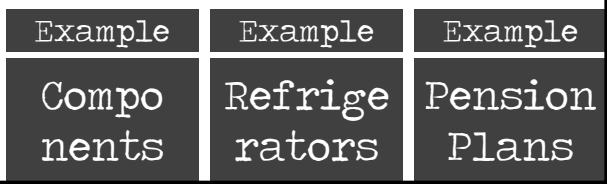
Many more are conceivable.

Example

WebDSL

Def: Coverage

DSLs are continuously evolved so the relevant parts of the deductive domain are supported.



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Semantics & Execution

expressivity
coverage
semantics
separation of concerns

completeness
paradigms
modularity
concrete syntax

process

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Static Semantics

Execution Semantics

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Static Semantics

Execution Semantics

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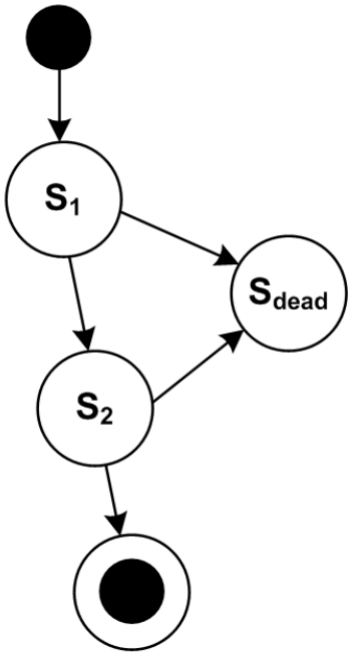
Static Semantics

Constraints
Type Systems



Unique State Names

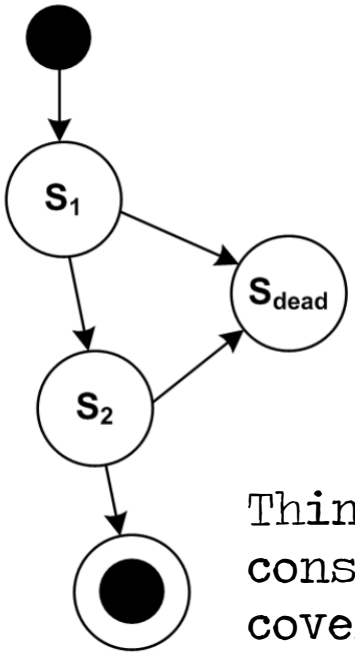
Unreachable States

Dead End States

…

Example

Exten
ded C



Unique State Names

Unreachable States

Dead End States

…

Easier to do on a declarative Level!

Thinking of all constraints is a coverage problem!

Example

Exten ded C


```
var int x = 2 * someFunction(sqrt(2));
```

Assign fixed types

Derive Types

Calculate Common Types

Check Type Consistency

What does a type system do?

Intent + Check

```
var int x = 2 *
    someFunction(sqrt(2));
```

Derive

```
var x = 2 * some
     Function(sqrt(2));
```

More code	More convenient
Better error messages	More complex checkers
Better Performance	Harder to understand for users


```
macro kompressorAus {
    set cc.c1->active = "aString"
    perform ccfanausscha
        set cc.ccfan->ac
    }
}
```

incompatible type BoolType|COMPARABLE and StringType (on a AssignmentStatement)

Example

Refrige rators

What does it all mean?

Execution Semantics

Def: Semantics

… via mapping to lower level

$$semantics(p_{L_D}) := q_{L_{D-1}}$$

$$where\ OB(p_{L_D}) == OB(q_{L_{D-1}})$$

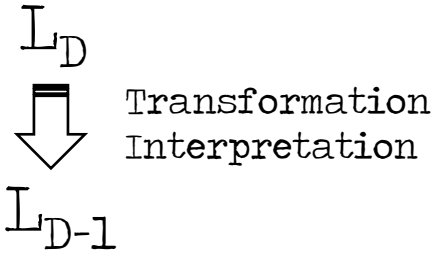
OB: Observable Behaviour (Test Cases)

Def: Semantics

… via mapping to lower level

$$semantics(p_{L_D}) := q_{L_{D-1}}$$

$$where\ OB(p_{L_D}) == OB(q_{L_{D-1}})$$



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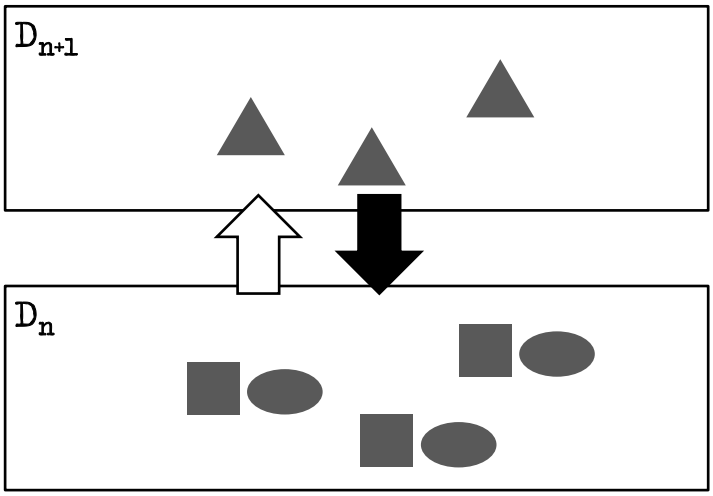
Transformation



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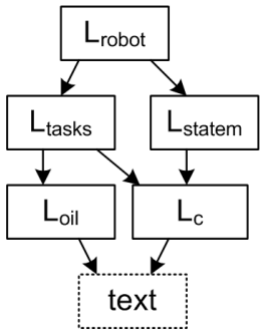
Transformation

```
module impl imports <<imports>> {

  int speed( int val ) {
    return 2 * val;
  }

  robot script stopAndGo
    block main on bump
      accelerate to 12 + speed(12) within 3000
      drive on for 2000
      turn left for 200
      decelerate to 0  within 3000
      stop

}
```



Example

Extended C

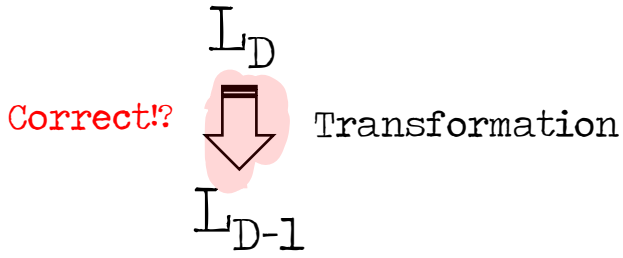
Transformation

L_D

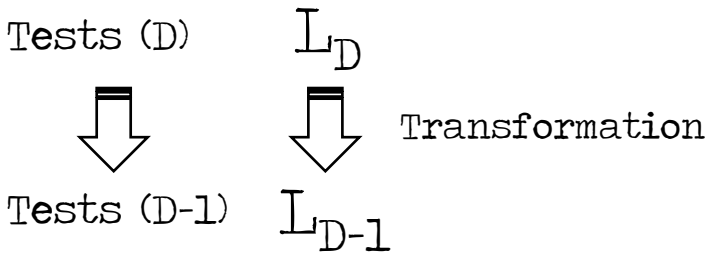
⇩ Transformation

L_{D-1} Known Semantics!

Transformation



Transformation



Run tests on both levels; all pass.
Coverage Problem!

```
parameter t_abtaustart: int
parameter t_abtaudauer: int
parameter T_abtauEnde: int

var tuerNachlaufSchwelle: int = 0

start:
    entry { state noCooling }

state noCooling:
    check ( (RC->needsCooling) && (cc.c1->stehz
        state rccooling
    }
    on isDown ( RC.rcdoor->open ) {
        set RC.rcfan->active = true
        set RC.rclight->active = false
        perform rcfanabschalttask after 10 {
            set RC.rcfan->active = false
        }
    }

state rccooling:
    entry { set RC.rcfan->active = true }
    check ( !(RC->needsCooling)  ) {
        state noCooling
    }
    on isDown ( RC.rcdoor->open ) {
        set RC.rcfan->active = true
        set RC.rclight->active = false
        set tuerNachlaufSchwelle = currStep + 30
    }
    exit {
        perform rcfanabschalttask after max( 5, tuerNachlaufSchwelle-currStep ) {
            set RC.rcfan->active = false
        }
    }
```

```
prolog {
    set RC->accumulatedRuntime = 80
}

step 10
assert-currentstate-is noCooling

mock: set RC->accumulatedRuntime = 110
step


mock: set RC.rceva->evaTemp = 10
assert-currentstate-is abtauen
assert-value cc.c1->active is false
mock: set RC->accumulatedRuntime = 0
step 5
assert-currentstate-is abtauen
assert-value cc.c1->active is false
step 15
assert-currentstate-is noCooling
```

Example

Refrige rators

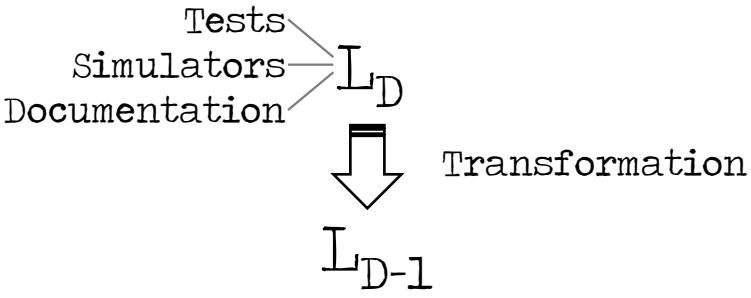
Transformation

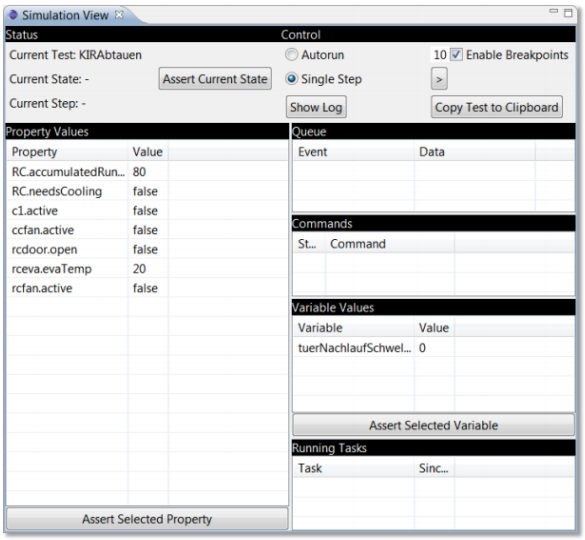
Name	Documentation	Tags	Valid time	Transaction time	Fixture	Product	Element	Expected value	Actual value
Accrued right at retireme			2006-12-31	2007-9-24	Jan De Jong	Old Age Pension	Accrued right	761.0402	761.0402
Accrued Right last final pay			2004-1-1	2007-9-24	Jan De Jong	Old Age Pension	Accrued right	705.0589	705.0589
premium last year			2006-1-1	2007-9-24	Jan De Jong	Old Age Pension	Premium old age pension	329.0625	329.0625
Accrued right at retireme 2)			2006-12-31	2007-9-24	Piet Van Dijk	Old Age Pension	Accrued right	740.94	724.7658
			1985-12-31	2007-9-24	Jan De Jong	Old Age Pension	Accrued Right in service period	73.661	73.661
			1985-12-31	2007-9-24	Jan De Jong	Old Age Pension	Years of service in service period	3.7534	3.7534
			1987-12-31	2007-9-24	Jan De Jong	Old Age Pension	Pension base average FP	7750	
			1998-12-31	2007-9-24	Jan De Jong	Old Age Pension	Accrued Right in service period	387.7449	
			1998-12-31	2007-9-24	Jan De Jong	Old Age Pension	Years of service in service period	10.8082	
			1998-12-31	2007-9-24	Jan De Jong	Old Age Pension	Pension base average FP	8250	

Example

Pension Plans

Transformation

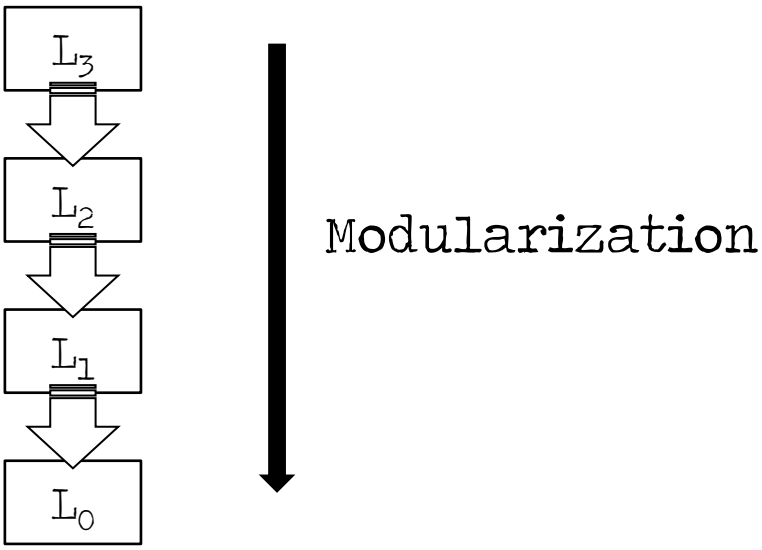




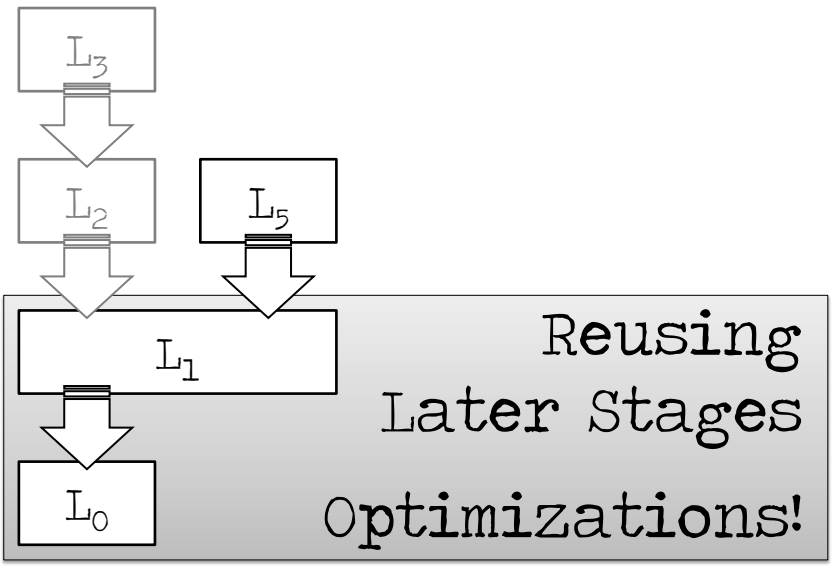
Example

Refrige rators

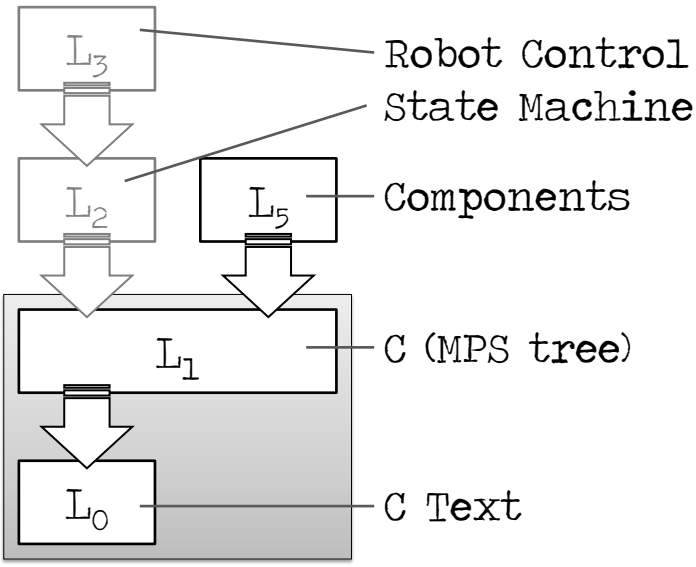
Multi-Stage



Multi-Stage: Reuse



Multi-Stage: Reuse



Example

Exten
ded C

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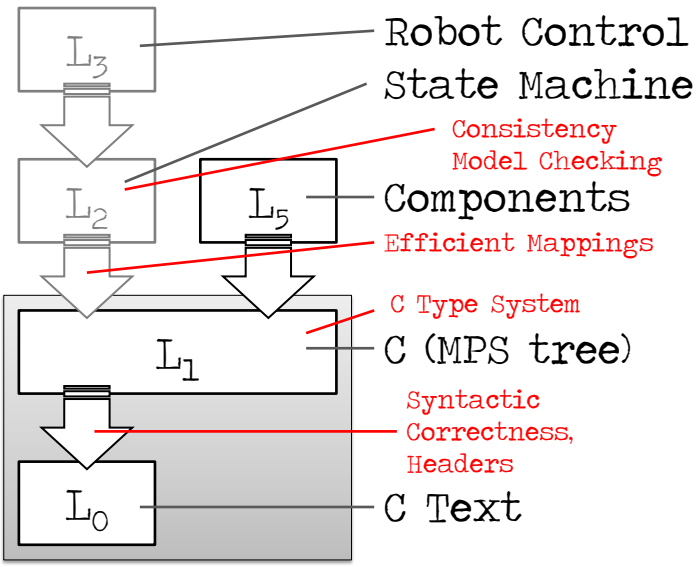
Multi-Stage: Reuse



Example

Exten
ded C

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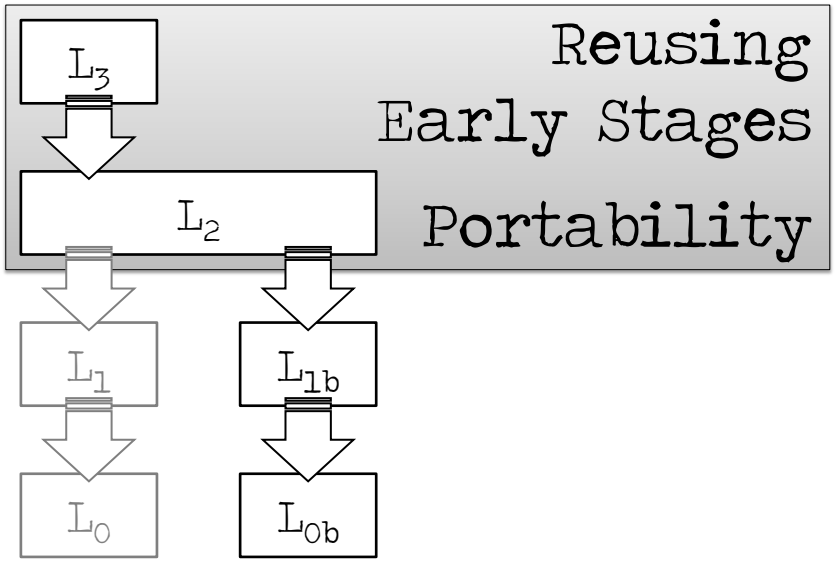
Multi-Stage: Reuse



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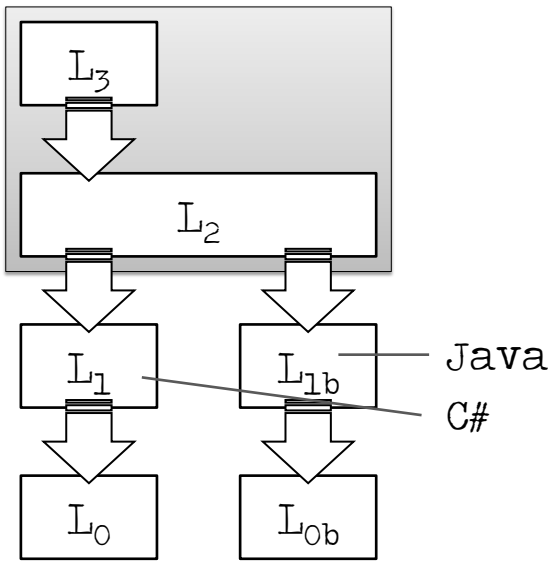
Multi-Stage: Reuse



Example

Exten
ded C

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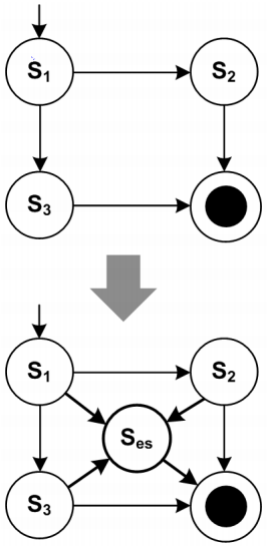
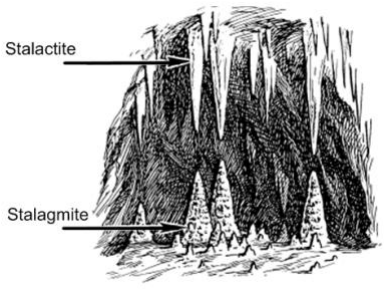
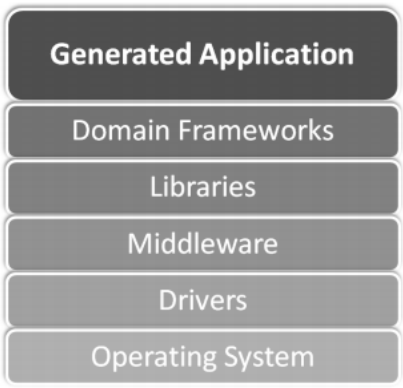
Multi-Stage: Preprocess



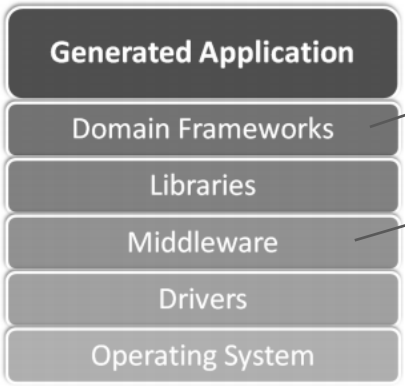
Adding an optional, modular emergency stop feature

Platform





Platform



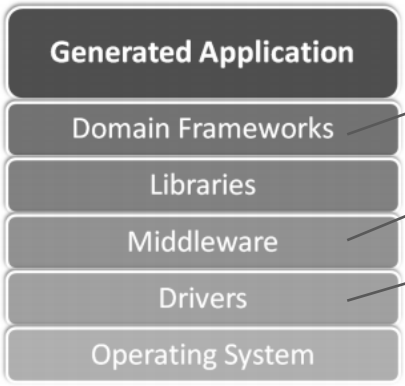
Temporal Data Versioning

Database Access
Transactions
Distribution
(JEE)

Example

Pension Plans

Platform



Data Collection

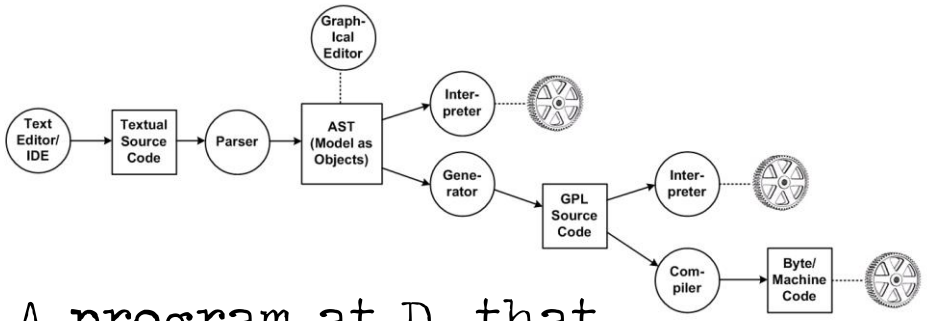
HAL

Device Drivers

Example

Refrige rators

Interpretation



A program at D_0 that
acts on the structure
of an input program at $D_{>0}$

Interpretation

A program at D_0 that
acts on the structure
of an input program at $D_{>0}$

imperative → step through
functional → eval recursively
declarative→ ? solver ?

Name	Documentation	Tags	Valid time	Transaction time	Fixture	Product	Element	Expected value	Actual value
Accrued right at retireme			2006-12-31	2007-9-24	Jan De Jong	Old Age Pension	Accrued right	761.0402	761.0402
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Example

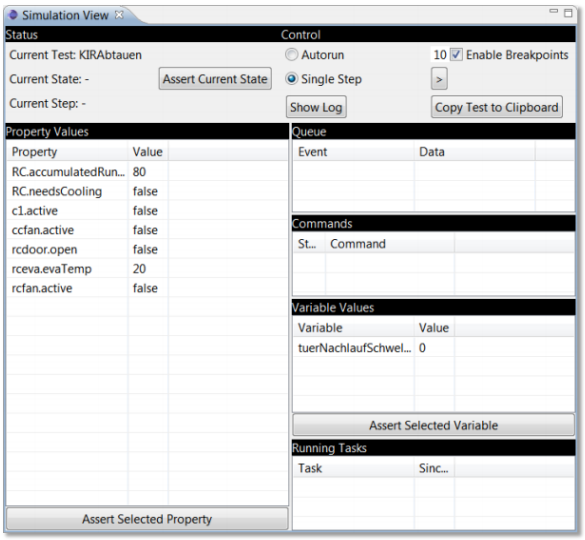
Pension Plans


```
parameter t_abtaustart: int
parameter t_abtaudauer: int
parameter T_abtauEnde: int

var tuerNachlaufSchwelle: int = 0

start:
    entry { state noCooling }

state noCooling:
    check ( (RC->needsCooling) && (cc.c1->stehz
        state rccooling
    }
    on isDown ( RC.rcdoor->open ) {
        set RC.rcfan->active = true
        set RC.rclight->active = false
        perform rcfanabschalttask after 10 {
            set RC.rcfan->active = false
        }
    }


state rccooling:
    entry { set RC.rcfan->active = true }
    check ( !(RC->needsCooling)  ) {
        state noCooling
    }
    on isDown ( RC.rcdoor->open ) {
        set RC.rcfan->active = true
        set RC.rclight->active = false
        set tuerNachlaufSchwelle = currStep + 30
    }
    exit {
        perform rcfanabschalttask after max( 5, tuerNachlaufSchwelle-currStep ) {
            set RC.rcfan->active = false
        }
    }
```

```
prolog {
    set RC->accumulatedRuntime = 80
}

step 10
assert-currentstate-is noCooling

mock: set RC->accumulatedRuntime = 110
step


mock: set RC.rceva->evaTemp = 10
assert-currentstate-is abtauen
assert-value cc.c1->active is false
mock: set RC->accumulatedRuntime = 0
step 5
assert-currentstate-is abtauen
assert-value cc.c1->active is false
step 15
assert-currentstate-is noCooling
```

Example

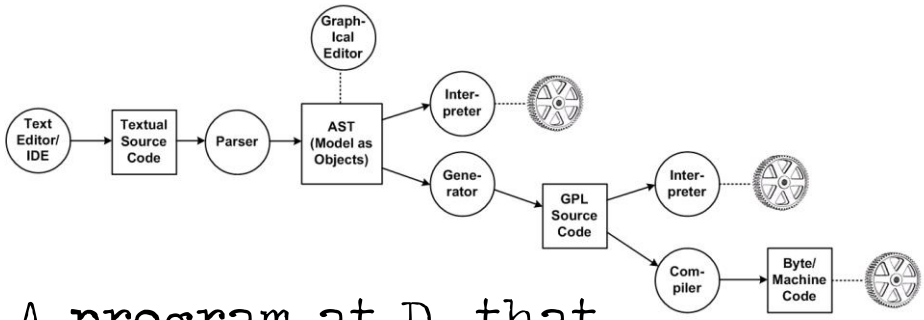
Refrige rators



Example

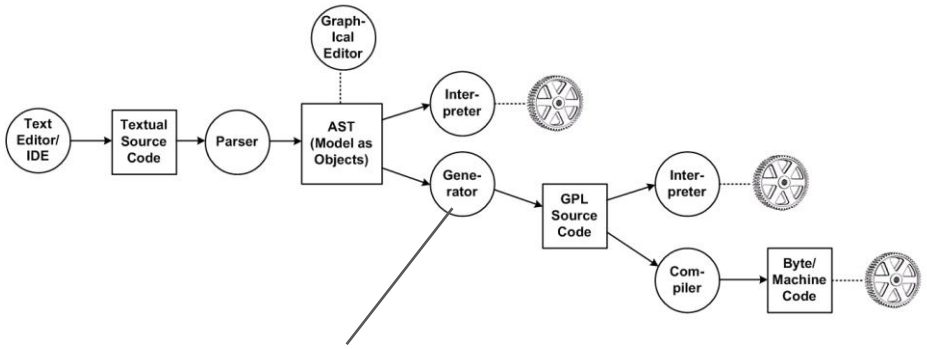
Refrige rators

Interpretation



A program at D_0 that acts on the structure of an input program at $D_{>0}$

Interpretation



An interpreter :-)

Transformation

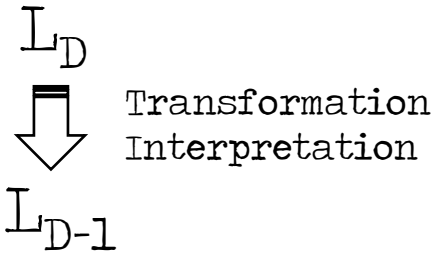
+ Code Inspection
+ Debugging
+ Performance & Optimization
+ Platform Conformance

Interpretation

+ Turnaround Time
+ Runtime Change

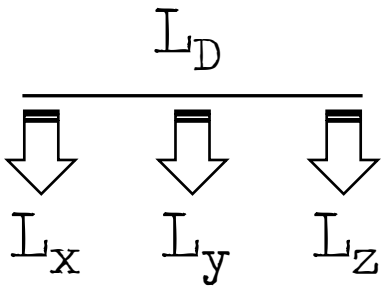
Def: Semantics

… via mapping to lower level



Multiple Mappings

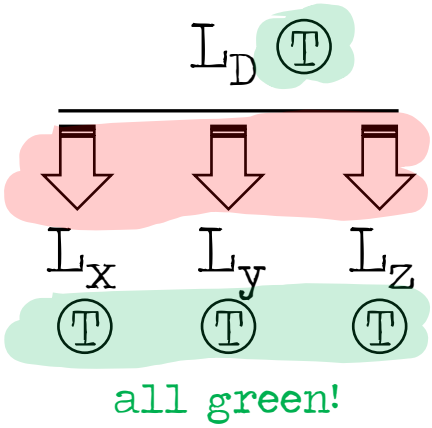
… at the same time



Similar Semantics?

Multiple Mappings

… at the same time



Similar Semantics?

all green!

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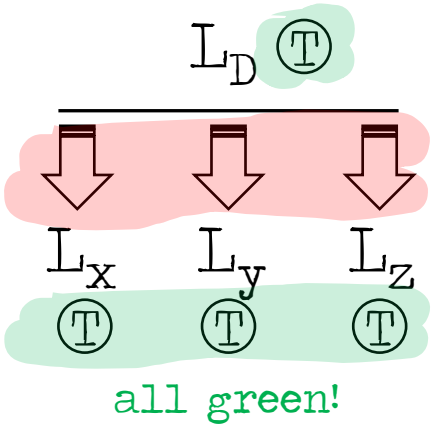
Multiple Mappings

… at the same time



Similar Semantics?

all green!

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Name	Documentation	Tags	Valid time	Transaction time	Fixture	Product	Element	Expected value	Actual value
Accrued right at retireme			2006-12-31	2007-9-24	Jan De Jong	Old Age Pension	Accrued right	761.0402	761.0402
Accrued Right last final pay			2004-1-1	2007-9-24	Jan De Jong	Old Age Pension	Accrued right	705.0589	705.0589
premium last year			2006-1-1	2007-9-24	Jan De Jong	Old Age Pension	Premium old age pension	329.0625	329.0625
Accrued right at retireme 2)			2006-12-31	2007-9-24	Piet Van Dijk	Old Age Pension	Accrued right	740.94	724.7658
			1985-12-31	2007-9-24	Jan De Jong	Old Age Pension	Accrued Right in service period	73.661	73.661
			1985-12-31	2007-9-24	Jan De Jong	Old Age Pension	Years of service in service period	3.7534	3.7534
			1987-12-31	2007-9-24	Jan De Jong	Old Age Pension	Pension base average FP	7750	7750
			1998-12-31	2007-9-24	Jan De Jong	Old Age Pension	Accrued Right in service period	387.7449	387.7449
			1998-12-31	2007-9-24	Jan De Jong	Old Age Pension	Years of service in service period	10.8082	10.8082
			1998-12-31	2007-9-24	Jan De Jong	Old Age Pension	Pension base average FP	8250	

Example

Pension Plans


```
parameter t_abtaustart: int
parameter t_abtaudauer: int
parameter T_abtauEnde: int

var tuerNachlaufSchwelle: int = 0

start:
    entry { state noCooling }

state noCooling:
    check ( (RC->needsCooling) && (cc.c1->stehz
        state rccooling
    }
    on isDown ( RC.rcdoor->open ) {
        set RC.rcfan->active = true
        set RC.rclight->active = false
        perform rcfanabschalttask after 10 {
            set RC.rcfan->active = false
        }
    }


state rccooling:
    entry { set RC.rcfan->active = true }
    check ( !(RC->needsCooling)  ) {
        state noCooling
    }
    on isDown ( RC.rcdoor->open ) {
        set RC.rcfan->active = true
        set RC.rclight->active = false
        set tuerNachlaufSchwelle = currStep + 30
    }
    exit {
        perform rcfanabschalttask after max( 5, tuerNachlaufSchwelle-currStep ) {
            set RC.rcfan->active = false
        }
    }
```

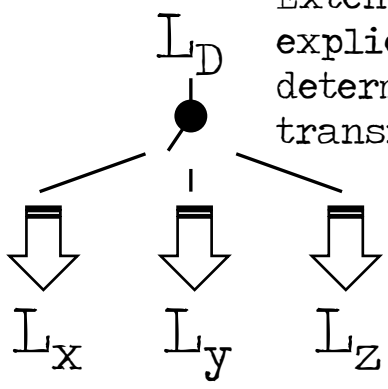
```
prolog {
    set RC->accumulatedRuntime = 80
}

step 10
assert-currentstate-is noCooling

mock: set RC->accumulatedRuntime = 110
step


mock: set RC.rceva->evaTemp = 10
assert-currentstate-is abtauen
assert-value cc.c1->active is false
mock: set RC->accumulatedRuntime = 0
step 5
assert-currentstate-is abtauen
assert-value cc.c1->active is false
step 15
assert-currentstate-is noCooling
```

Example

Refrige rators

Multiple Mappings

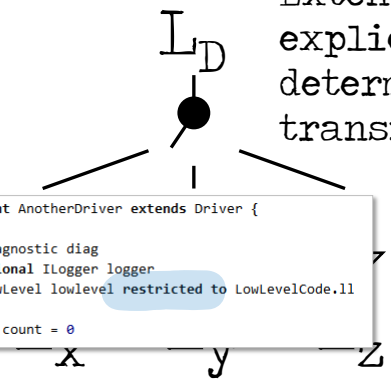
… alternatively, selectably



Extend L_D to include explicit data that determines transformation

Multiple Mappings

… alternatively, selectably



Extend L_D to include explicit data that determines transformation

```
exported component AnotherDriver extends Driver {
  ports:
    provides IDiagnostic diag
    requires optional ILogger logger
    requires ILowLevel lowlevel restricted to LowLevelCode.ll
  contents:
    field int8_t count = 0
```

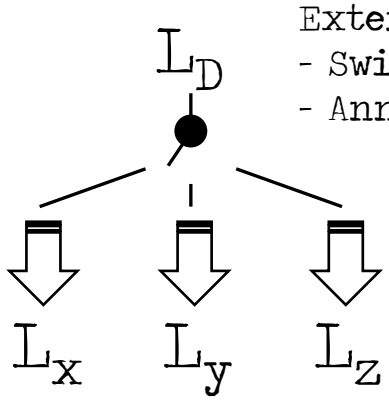
Restricted Port leads to reduced overhead C

Example

Extended C

Multiple Mappings

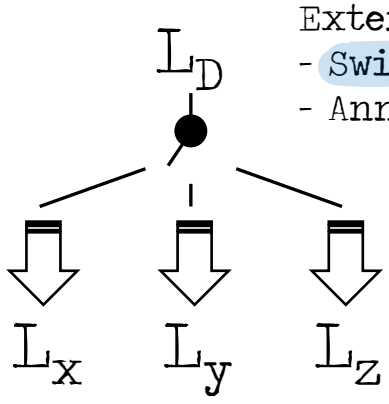
… alternatively, selectably



External Data:
- Switches
- Annotation Model

Multiple Mappings

… alternatively, selectably



External Data:
- Switches
- Annotation Model

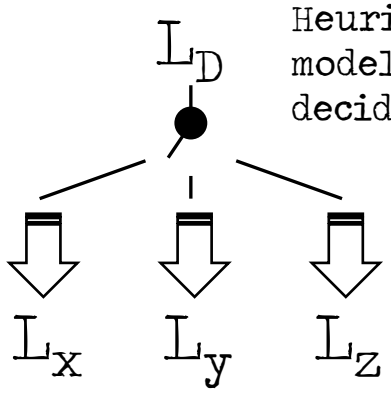
Switch Control
Java vs. C

Example

Pension Plans

Multiple Mappings

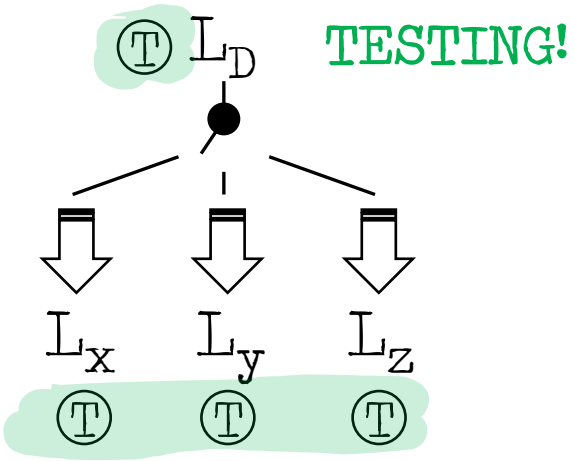
… alternatively, selectably



Heuristics: Analyze model to try to decide

Multiple Mappings

… alternatively, selectably



TESTING!

Reduced Expressiveness

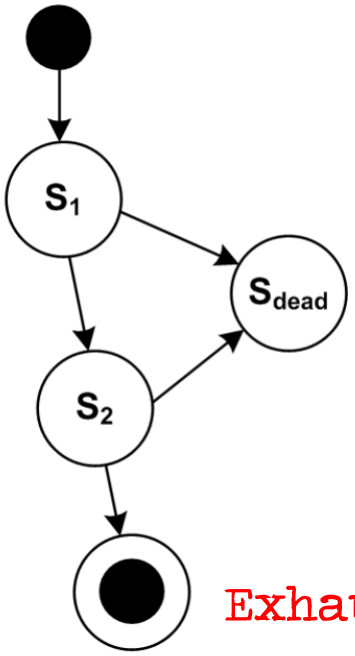
bad? maybe.

good? maybe!

Model Checking

SAT Solving

Exhaustive Search, Proof!



Unique State Names

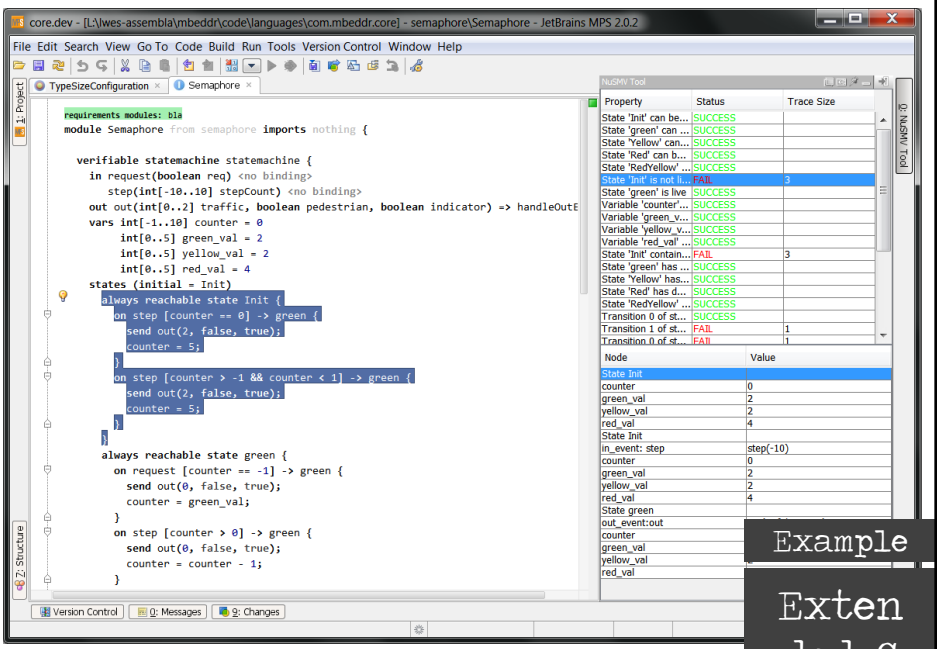
Unreachable States

Dead End States

Guard Decidability

Reachability

Exhaustive Search, Proof!



Example

Exten ded C


```
c/s interface Decider {
  int decide(int x, int y) pre
}

component AComp extends nothing {
  ports:
    provides Decider decider
  contents:
    int decide(int x, int y) <- op decider.decide {
      return int, 0
    }
}
```

	x == 0	x > 0
y == 0	0	1
y > 0	1	2

;

Example

Exten ded C

Separation of Concerns

expressivity	completeness
coverage	paradigms
semantics	modularity
separation of concerns	concrete syntax

process

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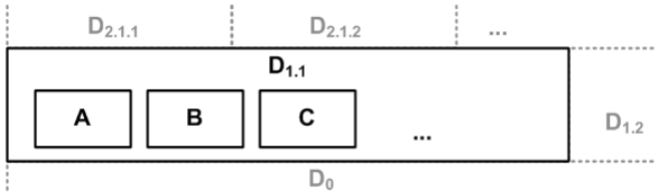
Several Concerns

… in one domain



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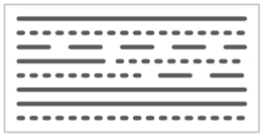
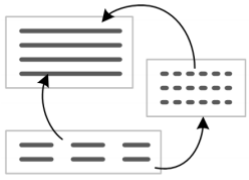
Several Concerns

… in one domain

integrated into one fragment



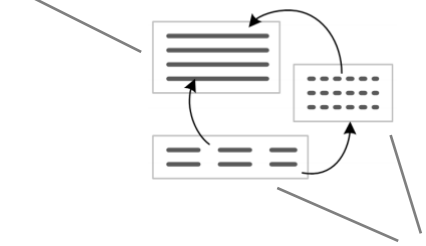
separated into several fragments



Viewpoints

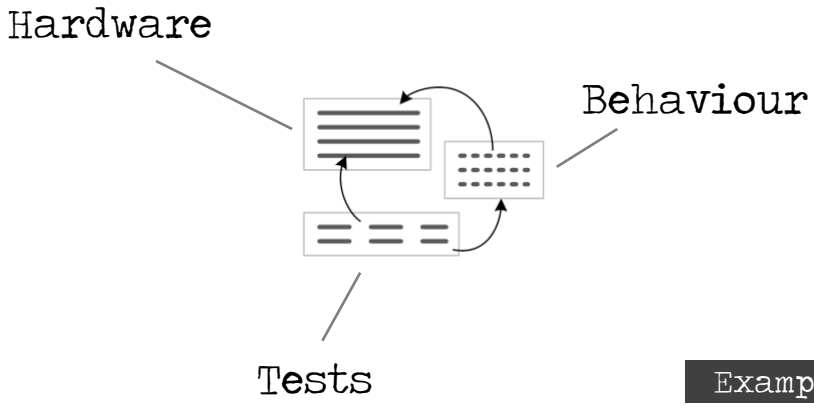
independent

$$\forall r \in Refs_f \mid fo(r.to) = fo(r.from) = f$$
$$\forall e \in E_f \mid lo(co(e)) = l$$



dependent

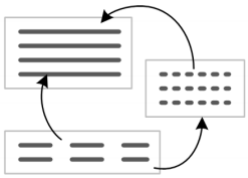
Viewpoints



Example

Refrige rators

Viewpoints: Why?



Sufficiency

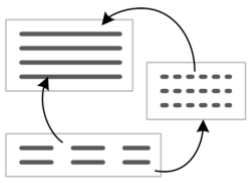
Different Stakeholders

Different Steps in Process - VCS unit!

Viewpoints

Hardware

Product Management



Behaviour

Thermo-dynamics-Experts

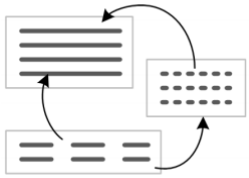
Tests

Example

Refrige rators

Viewpoints

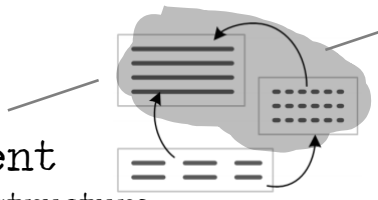
independent



sufficient?

contains all the data for running a meaningful transformation

Viewpoints



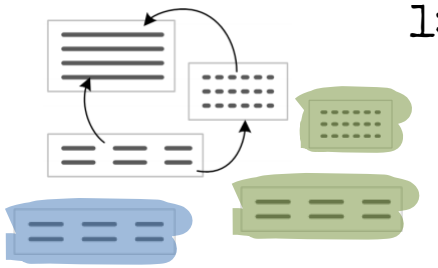
sufficient
implementation code

sufficient
Hardware structure documentation

Example

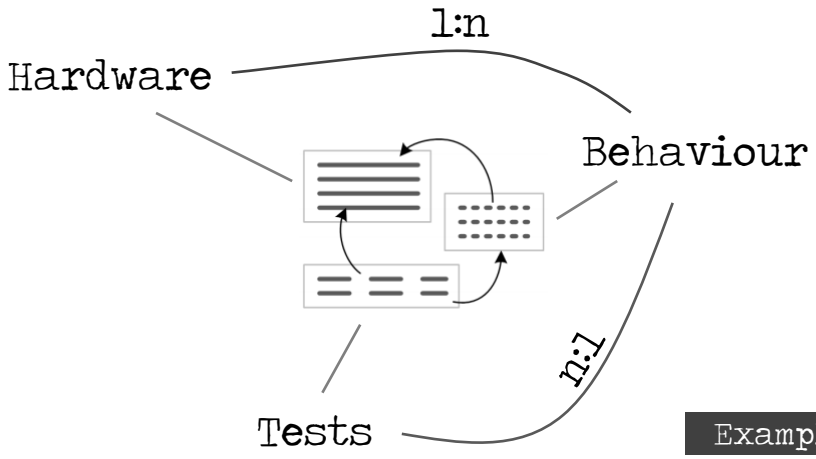
Refrige rators

Viewpoints: Why?



1:n Relationships

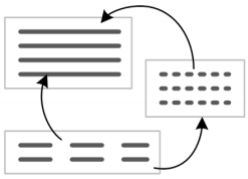
Viewpoints



Example

Refrige rators

Viewpoints

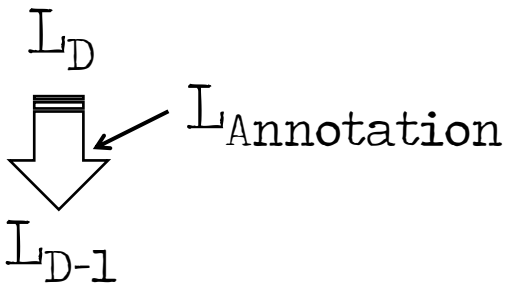


Well-defined Dependencies

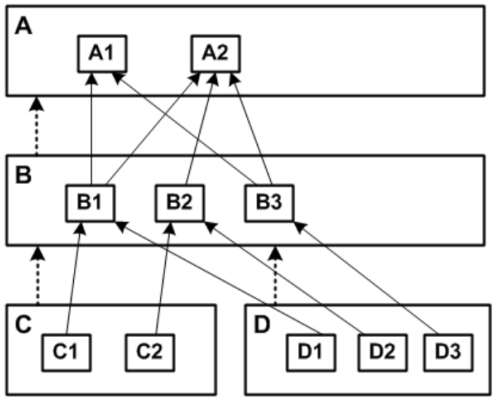
No Cycles!

Avoid Synchronization!
(unless you use a projectional editor)

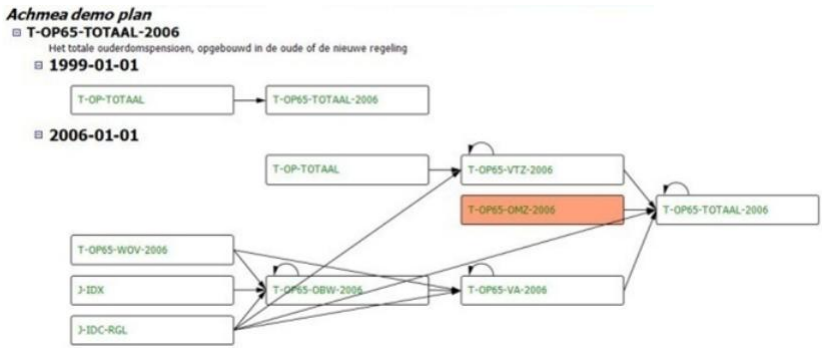
Viewpoints: Why?



Progressive Refinement



Views on Programs



Example

Pension Plans

Completeness

expressivity
coverage
semantics
separation of concerns

completeness
paradigms
modularity
concrete syntax

process

Can you generate 100% of the code from the DSL program?

More generally: all of D_{-1}

Semantics:

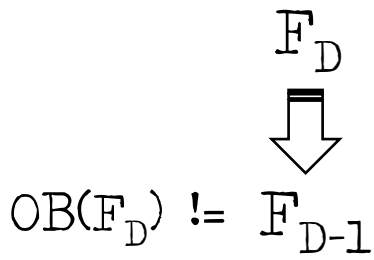
$$semantics(p_{L_D}) := q_{L_{D-1}}$$
$$where\ OB(p_{L_D}) == OB(q_{L_{D-1}})$$

Introduce G ("generator"):

$OB(p) == OB(G(p)) == OB(q)$ complete

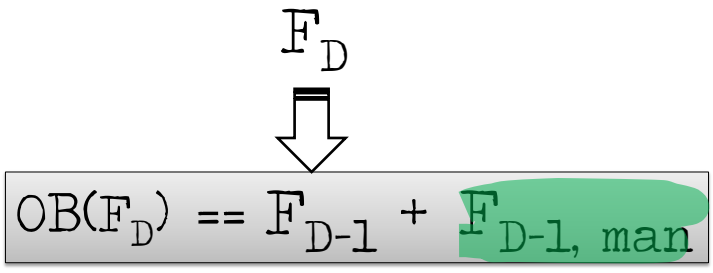
$OB(G(p)) \subset OB(p)$ incomplete

Incomplete: What to do?



Incomplete: What to do?

Manually written code!



Manually written code?

Call "black box" code (foreign functions)

Manually written code?

Call "black box" code (foreign functions)

Embed L_{D-1} code in L_D program

Manually written code?

Call "black box" code (foreign functions)

Embed L_{D-1} code in L_D program

Embed C statements in components, state machines or decision tables

Example

Manually written code?

Call "black box" code (foreign functions)

Embed L_{D-1} code in L_D program

Use composition mechanisms of L_{D-1} (inheritance, patterns, aspects, …)

Manually written code?

Call "black box" code (foreign functions)

Embed L_{D-1} code in L_D program

Use composition mechanisms of L_{D-1} (inheritance, patterns, aspects, …)

Generate base classes with abstract methods; implement in subclass

Example

Components

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Manually written code?

Call "black box" code (foreign functions)

Embed L_{D-1} code in L_D program

Use composition mechanisms of L_{D-1} (inheritance, patterns, aspects, …)

Use protected regions (if you really have to…)

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Manually written code?

Call "black box" code (foreign functions)

Embed L_{D-1} code in L_D program

Use composition mechanisms of L_{D-1} (inheritance, patterns, aspects, …)

Use protected regions (if you really have to…) DON'T!

Incomplete: When?

Good for technical DSLs: Devs write L_{D-1} code

Bad for business DSLs. Maybe use a L_{D-1} std lib that L_D code can call into?

Incomplete: When?

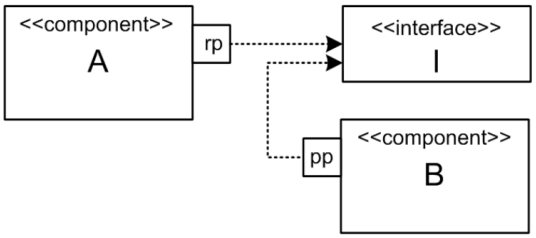
Good for technical DSLs: Devs write L_{D-1} code

Example	Example
Extended C	Components

Bad for business DSLs.
Maybe use a L_{D-1} std lib that L_D code can call into?

Example	Example	Example
Refrigerators	Pension Plans	Web DSL

Prevent Breaking Promises!

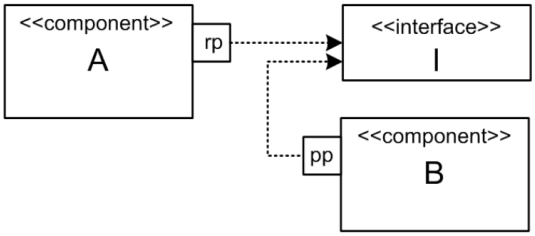



```
class B extens BBase {

  public void doSomething() {
    Registry.get(„A“).someMethod();
  }

}
```

Prevent Breaking Promises!



Better:

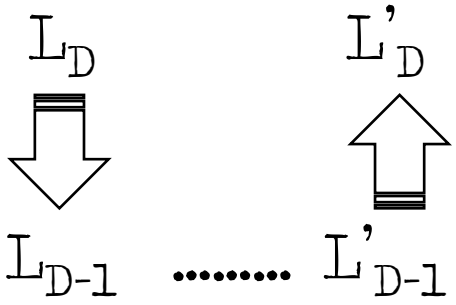
Dependency Injection

Static analysis tools

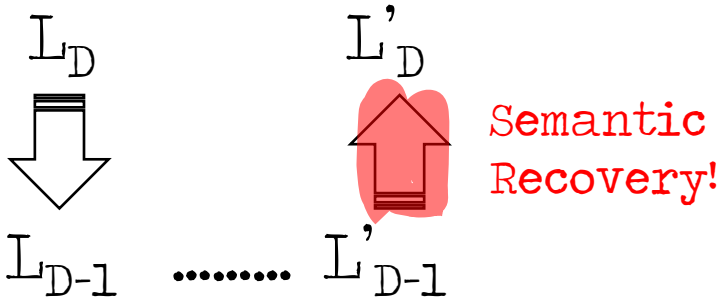
Example

Components

Roundtripping



Roundtripping - Don't!



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Fundamental Paradigms

expressivity	completeness
coverage	paradigms
semantics	modularity
separation of concerns	concrete syntax

process

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Structure

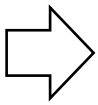
Modularization, Visibility

- Namespaces,
- public/private
- importing

Structure

Modularization, Visibility

- Namespaces,
- public/private
- importing



- divide & conquer
- reuse
- stakeholder integration

Structure

Partitioning (Files)

VCS Unit
Unit of sharing
Unit of IP

!= logical modules

may influence language design

Structure

Modularization, Visibility

```
module Module1 from HPL.main imports Module2 {

  exported var int aReallyGlobalVar;

  struct aLocallyVisibleStruct {
    int x;
    int y;
  };

  exported int anExportedFunction() {
    return anImportedFunction/Module2();
  } anExportedFunction (function)
}
```

Example

Exten
ded C

Structure

Modularization, Visibility

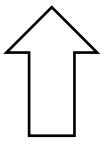
```
namespace com.mycompany.test {
  system testSystem {
    instance dc: DelayCalculator
    instance screen1: InfoScreen
    instance screen2: InfoScreen
    connect dc.screens to
      (screen1.default, screen2.default)
  }
}
```

Example

Compo nents

Structure

Partitioning (Files)



change impact
link storage
model organization
tool integration

Structure

Spec vs. Implementation

⇨ plug in different Impls
different stakeholders

Structure

Spec vs. Impl.

```
exported c/s interface ITrafficLights {
  int8_t setColor(TLCommand cmd) ;
}

c/s interface IDriver {
  int8_t setDriverValue(int8_t addr, int8_t value) ;
}

c/s interface IDiagnostic {
  int8_t getCount() ;
}

c/s interface ILogger {
  void log(string message) ;
}

c/s interface ILowLevel {
  int8_t doSomeLowlevelStuff(int8_t y) ;
}
```

```
exported component AnotherDriver extends Driver {
  ports:
    provides IDiagnostic diag
    requires optional ILogger logger
    requires ILowLevel lowlevel restricted to LowLevelCod
  contents:
    field int8_t count = 0

    override int8_t setDriverValue(int8_t addr, int8_t value) <- op cmd.setDriverValue {
      with port (logger) { logger.log("SomeMessage"); } with port
      lowlevel.doSomeLowlevelStuff(10);
      count++;
      return 1;
    }

    int8_t diag_getCount() <- op diag.getCount {
      return count;
    }
}
```

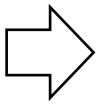
Example

Exten
ded C

Structure

Specialization

Liskov substitution P
leaving holes ("abstract")



variants (in space)
evolution (over time)

Structure

Specialization

Pension Plans can inherit from other plans.

Rules can be abstract;

Plans with abstract rules are abstact

Example

Compo nents

Structure

Superposition, Aspects

- merging
- overlay
- AOP

⇨ modularize cross-cuts

Structure

Superposition, Aspects

```
component DelayCalculator {
  …
}
component AircraftModule {
  …
}
component InfoScreen {
  …
}
```

```
aspect (*) component {
   provides mon: IMonitoring
}
```

```
component DelayCalculator {
  …
  provides mon: IMonitoring
}
component AircraftModule {
  …
  provides mon: IMonitoring
}
component InfoScreen {
  …
  provides mon: IMmonitoring
}
```

Example

Compo nents

Behavior

Not all DSLs specify behavior

Some just **declare** behavior

This section is
not for those!

Behavior

Imperative

sequence of statements
changes program state

write	understand	debug	analyze	performance
simple	simple -	simple (step)	hard	good

Behavior

Imperative

sequence of statements
changes program state

```
state rccooling:
    entry { set RC.rcfan->active = true }
    check ( !(RC->needsCooling)  ) {
        state noCooling
    }
    on isDown ( RC.rcdoor->open ) {
        set RC.rcfan->active = true
        set RC.rclight->active = false
        set tuerNachLaufSchwelle = currStep + 30
    }
    exit {
        perform rcfanabschalttask after max( 5, tuerNachLaufSchwelle-currStep ) {
            set RC.rcfan->active = false
        }
    }
```

Example

Refrige rators

Behavior

Functional

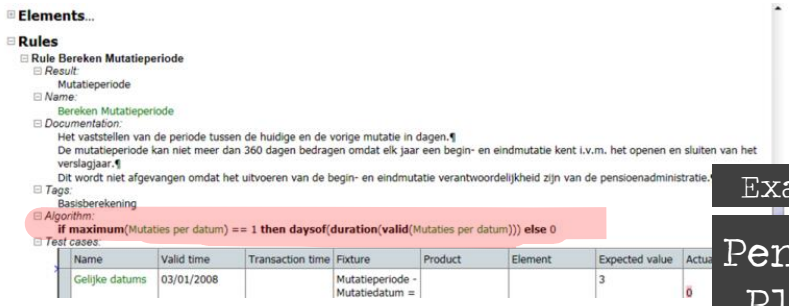
functions call other functions.
no state. No aliasing.

write	understand	debug	analyze	performance
simple -	simple	simple (tree)	good	good -

Behavior

Functional

functions call other functions.
no state. No aliasing.

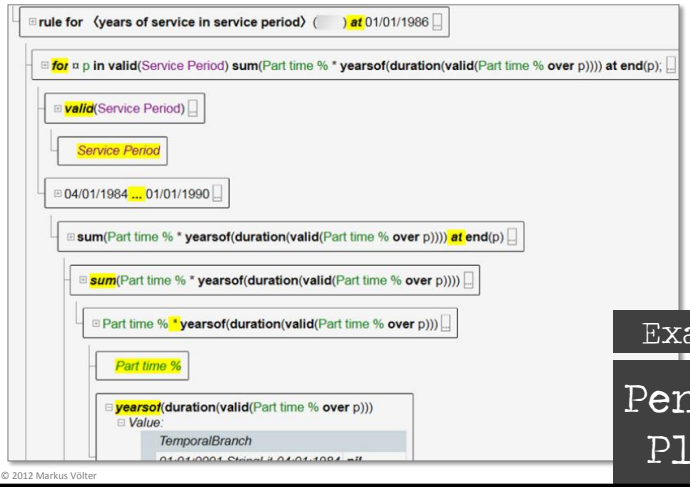


Example

Pension Plans

Behavior

Functional



Example

Pension Plans

Behavior

Functional

- pure expressions are a subset of functional (operators hard-wired)
- guards
- preconditions
- derived attributes

Behavior

Declarative

- only facts and goals.
- no control flow.
- eval engine, solver (several)

write	understand	debug	analyze	performance
simple	simple -	hard	depends	often bad

Behavior

Declarative

- concurrency
- constraint programming
- solving
- logic programming

Behavior

Declarative

- only facts and goals.
- no control flow.
- eval engine, solver (several)

```
section posts
  define page post(p: Post, title: String) {
    title{ output(p.title) }
    bloglayout(p.blog){
      placeholder view { postView(p) }
      postComments(p)
    }
  }
  define permalink(p: Post) {
    navigate post(p, p.urlTitle) { elements }
  }
```

Example

Web DSL

Behavior

Declarative

```
synchronous blockType org::eclipselabs::damos::library::base::_discrete::DiscreteDerivative

input u
output y

parameter initialCondition = 0
parameter gain = 1(s) // normalized

behavior {

	stateful func main<initialCondition, gain, fs>(u) -> y {
		check<0, 1(s), 1(1/s)>(real) -> real

		static assert u is real() :
			error "Input value must be numeric"

		static assert initialCondition is real() :
			error "Initial condition must be numeric"

		static assert initialCondition is real() && u is real() => unit(initialCondition) == unit(u) :
			error "Initial condition and input value must have same unit"

		static assert gain is real() :
			error "Gain value must be numeric"

		eq u{-1} = initialCondition
		eq y{n} = fs * gain * (u{n} - u{n-1})
	}

}
```

Example

Extended C

Behavior

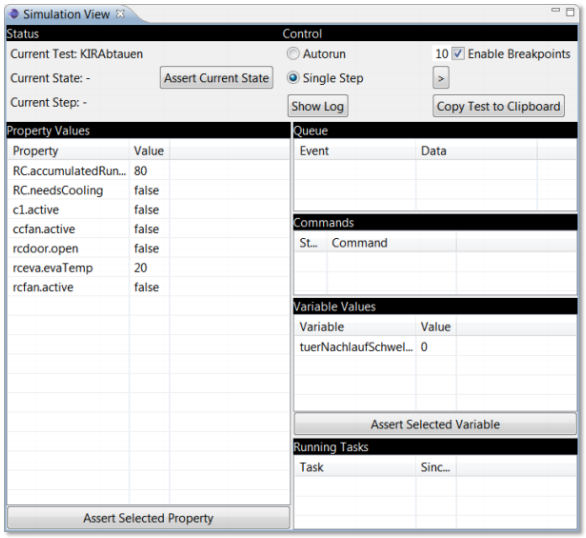
Reactive

reactions to events, more events are produced. Communication via events and channels/queues

write	understand	debug	analyze	performance
simple	simple/hard	hard	simple	can be good

Behavior

Reactive

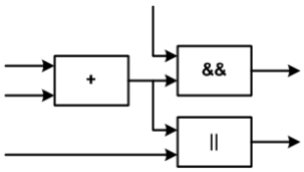


Example

Refrige rators

Behavior

Data Flow

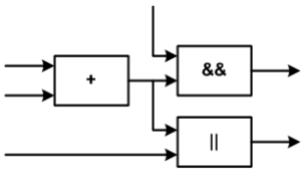


chained blocks consume continuous data that flows from block to block

write	understand	debug	analyze	performance
simple -	simple/hard	hard	simple	can be good

Behavior

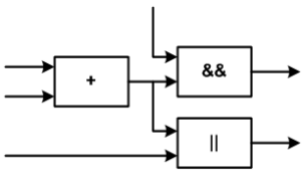
Data Flow



continuous, calc on change
quantized, calc on new data
time triggered, calc every x

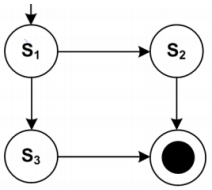
Behavior

Data Flow



Embedded Programming
Enterprise ETL & CEP

Behavior



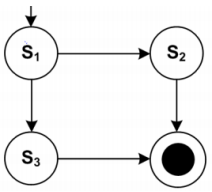
State Based

states, transitions, guards, reactions

event driven, timed

write	understand	debug	analyze	performance
simple -	simple/hard	s/h	simple +	can be good

Behavior



State Based

```
start:
    entry { state noCooling }

state noCooling:
    check ( (RC->needsCooling) && (cc.c1->stehzeit > 333) ) {
        state rccooling
    }
    on isDown ( RC.rcdoor->open ) {
        set RC.rcfan->active = true
        set RC.rclight->active = false
        perform rcfanabschalttask after 10 {
            set RC.rcfan->active = false
        }
    }


state rccooling:
    entry { set RC.rcfan->active = true }
    check ( !(RC->needsCooling)  ) {
        state noCooling
    }
    on isDown ( RC.rcdoor->open ) {
        set RC.rcfan->active = true
        set RC.rclight->active = false
        set tuerNachLaufSchwelle = currStep + 30
    }
    exit {
        perform rcfanabschalttask after max( 5, tuerNachLaufSchwelle-currStep ) {
            set RC.rcfan->active = false
        }
    }
```

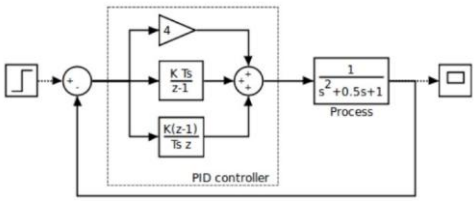
Example

Refrige rators

Behavior

Combinations

data flow uses functional, imperative or declarative lang inside block




```
synchronous blockType org::eclipselabs::damos::library::base::_discrete::DiscreteDerivative

input u
output y

parameter initialCondition = 0
parameter gain = 1(s) // normalized

behavior {

        stateful func main<initialCondition, gain, fs>(u) -> y {
                check<0, 1(s), 1(1/s)>(real) -> real

                static assert u is real() :
                        error "Input value must be numeric"

                static assert initialCondition is real() :
                        error "Initial condition must be numeric"

                static assert initialCondition is real() && u is real() => unit(initialCondition) == unit(u) :
                        error "Initial condition and input value must have same unit"

                static assert gain is real() :
                        error "Gain value must be numeric"

                eq u[-1] = initialCondition
                eq y[n] = fs * gain * (u[n] - u[n-1])
        }
}
```


Behavior

Combinations

state machines use expressions in guards and often an imperative lang in actions

Behavior

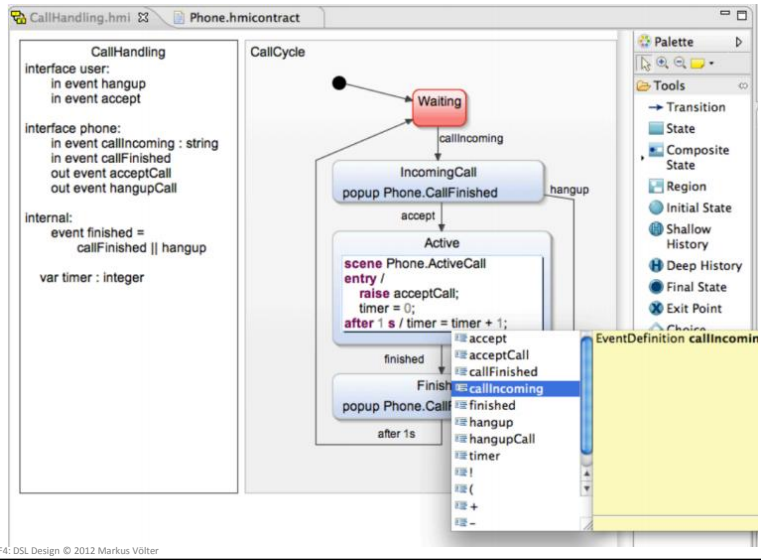
Combinations

```
start:
    entry { state noCooling }

state noCooling:
    check ( (RC->needsCooling) && (cc.c1->stehzeit > 333) ) {
        state rccooling
    }
    on isDown ( RC.rcdoor->open ) {
        set RC.rcfan->active = true
        set RC.rclight->active = false
        perform rcfanabschalttask after 10 {
            set RC.rcfan->active = false
        }
    }


state rccooling:
    entry { set RC.rcfan->active = true }
    check ( !(RC->needsCooling)  ) {
        state noCooling
    }
    on isDown ( RC.rcdoor->open ) {
        set RC.rcfan->active = true
        set RC.rclight->active = false
        set tuerNachLaufSchwelle = currStep + 30
    }
    exit {
        perform rcfanabschalttask after max( 5, tuerNachLaufSchwelle-currStep ) {
            set RC.rcfan->active = false
        }
    }
```

Example

Refrige rators

Behavior



Behavior

Combinations

purely structural languages often use expressions to specify constraints

```
c/s interface IDriver {
  int setDriverValue(int addr, int value)
    pre value > 0
}
```

Example

Extended C

Language Modularity

expressivity	completeness
coverage	paradigms
semantics	modularity
separation of concerns	concrete syntax

process

Language Modularity, Composition and Reuse (LMR&C)

increase efficiency of DSL development

4 ways of composition:

Referencing
Reuse
Extension
Reuse

Language Modularity, Composition and Reuse (LMR&C)

increase efficiency of DSL development

4 ways of composition:

distinguished regarding **dependencies** and **fragment structure**

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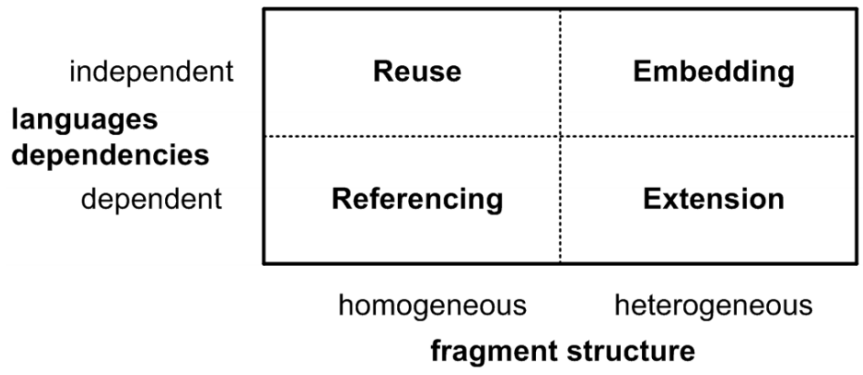
Dependencies:

do we have to know about the reuse when designing the languages?

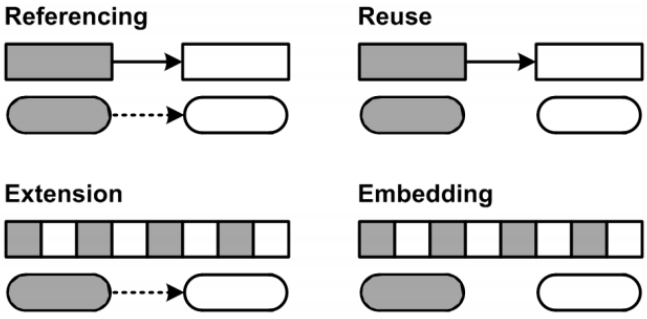
Fragment Structure:

homogeneous vs. heterogeneous („mixing languages")

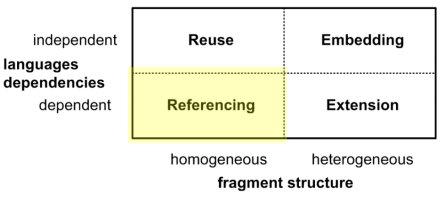
Dependencies & Fragment Structure:

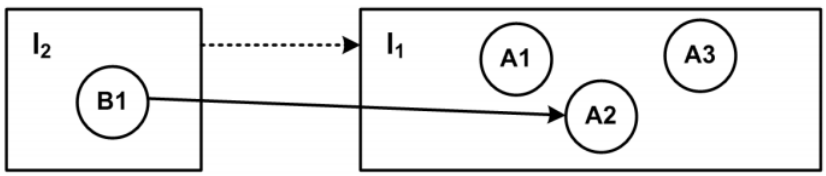


Dependencies & Fragment Structure:

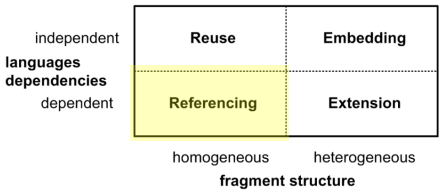


Referencing

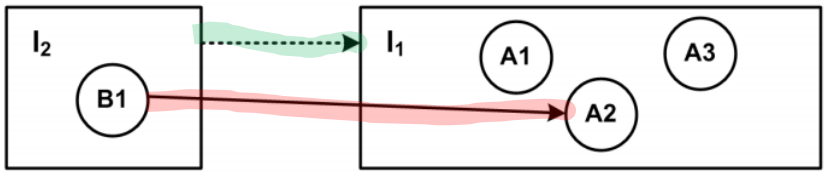




Referencing



Dependent

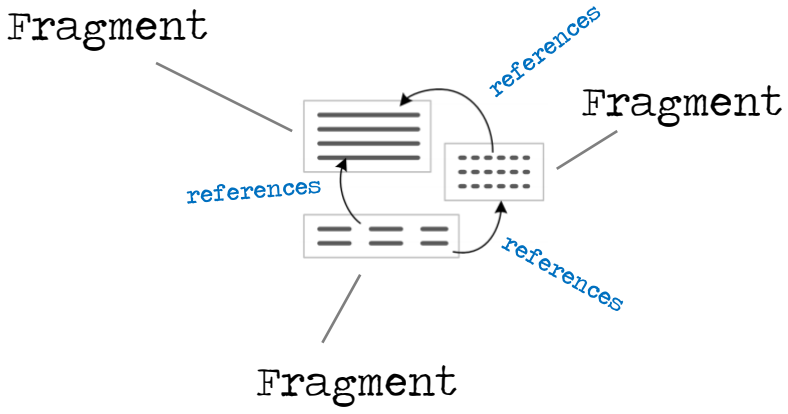


No containment

Referencing

Used in Viewpoints

Referencing



Referencing

```
parameter t_abtaustart: int
parameter t_abtaudauer: int
parameter T_abtauEnde: int

var tuerNachlaufSchwelle: int = 0

start:
    entry { state noCooling }

state noCooling:
    check ( (RC->needsCooling) && (cc.c1->stehz
        state rccooling
    }
    on isDown ( RC.rcdoor->open ) {
        set RC.rcfan->active = true
        set RC.rclight->active = false
        perform rcfanabschalttask after 10 {
            set RC.rcfan->active = false
        }
    }


state rccooling:
    entry { set RC.rcfan->active = true }
    check ( !(RC->needsCooling)  ) {
        state noCooling
    }
    on isDown ( RC.rcdoor->open ) {
        set RC.rcfan->active = true
        set RC.rclight->active = false
        set tuerNachlaufSchwelle = currStep + 30
    }
    exit {
        perform rcfanabschalttask after max( 5, tuerNachlaufSchwelle-currStep ) {
            set RC.rcfan->active = false
        }
    }
```

```
prolog {
    set RC->accumulatedRuntime = 80
}

step 10
assert-currentstate-is noCooling

mock: set RC->accumulatedRuntime = 110
step


mock: set RC.rceva->evaTemp = 10
assert-currentstate-is abtauen
assert-value cc.c1->active is false
mock: set RC->accumulatedRuntime = 0
step 5
assert-currentstate-is abtauen
assert-value cc.c1->active is false
step 15
assert-currentstate-is noCooling
```

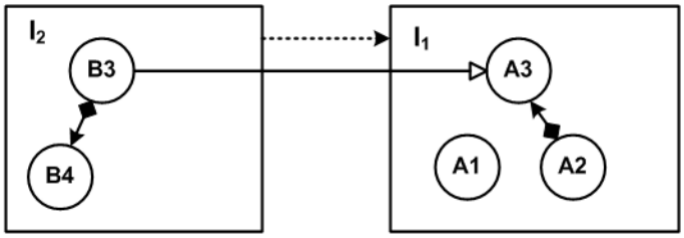
Example

Refrige rators

Extension

languages dependencies	homogeneous	heterogeneous
independent	Reuse	Embedding
dependent	Referencing	Extension

fragment structure

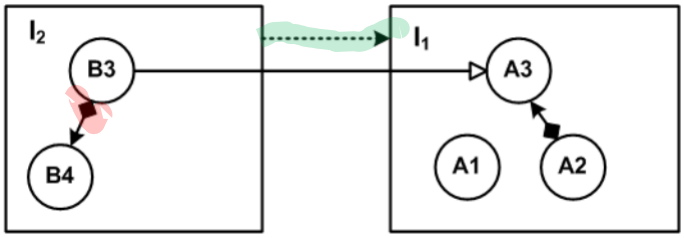


Extension

languages dependencies	homogeneous	heterogeneous
independent	Reuse	Embedding
dependent	Referencing	Extension

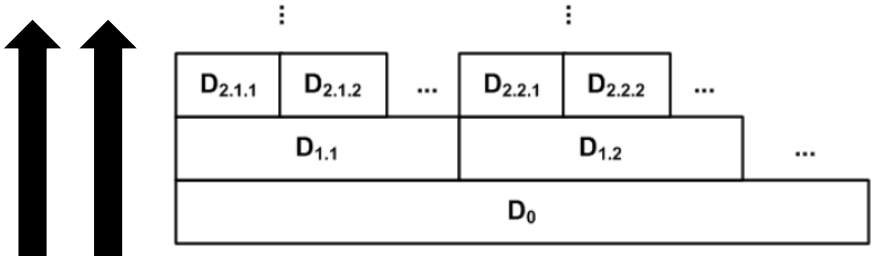
fragment structure

Dependent



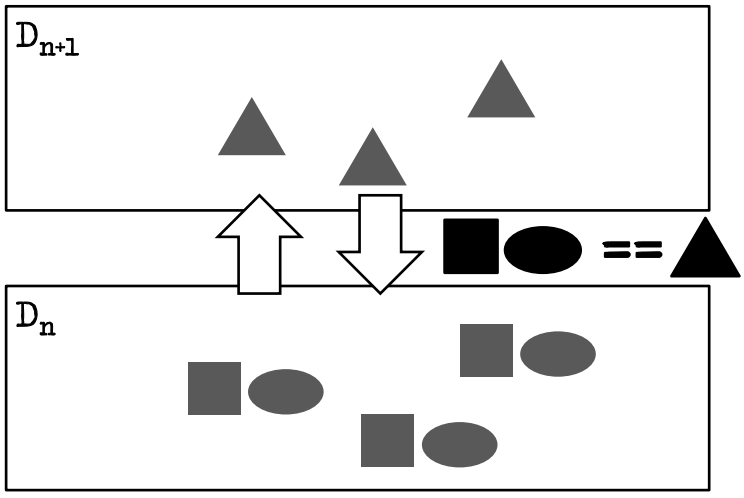
Containment

Extension

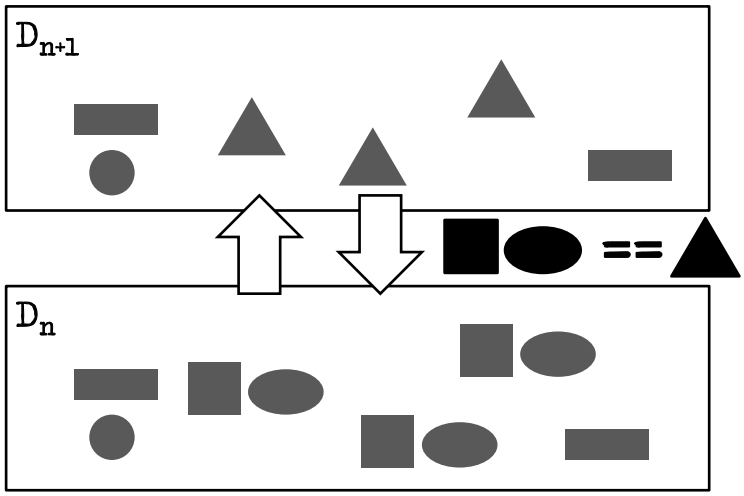


more specialized domains
more specialized languages

Extension

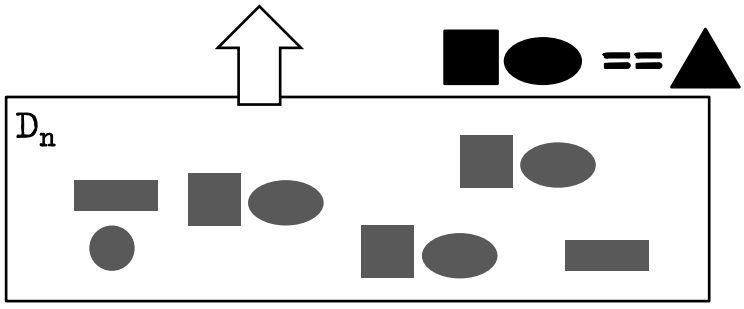


Extension



Extension

Good for **bottom-up** (inductive) domains, and for use by **technical** DSLs (people)



Extension

Drawbacks

- tightly bound to base
- potentially hard to analyze the combined program

Extension

```
module main imports OsekKernel, EcAPI, BitLevelUtilies {

  constant int WHITE = 500;
  constant int BLACK = 700;
  constant int SLOW = 20;
  constant int FAST = 40;

  statemachine linefollower {
    event initialized;
    initial state initializing {
      initialized [true] -> running
    }
    state running { }
  }

  initialize {
    ecrobot_set_light_sensor_active
              (SENSOR_PORT_T::NXT_PORT_S1);
    event linefollower:initialized
  }

  terminate {
    ecrobot_set_light_sensor_inactive
              (SENSOR_PORT_T::NXT_PORT_S1);
```

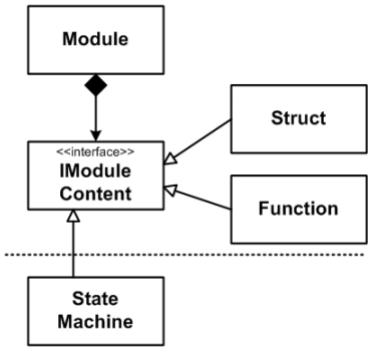
```
task run cyclic prio = 1 every = 2 {
  stateswitch linefollower
    state running
      int32 light = 0;
      light = ecrobot_get_light_sensor
                        (SENSOR_PORT_T::NXT_PORT_S1);
      if ( light < ( WHITE + BLACK ) / 2 ) {
        updateMotorSettings(SLOW, FAST);
      } else {
        updateMotorSettings(FAST, SLOW);
      }
    default
      <noop>;
}

void updateMotorSettings( int left, int right ) {
  nxt_motor_set_speed(MOTOR_PORT_T::NXT
  nxt_motor_set_speed(MOTOR_PORT_T::NXT
}
```

Example

Extended C

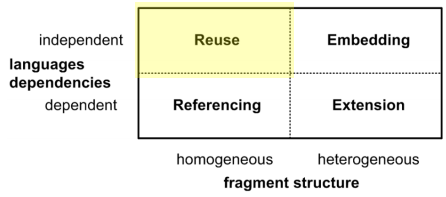
Extension

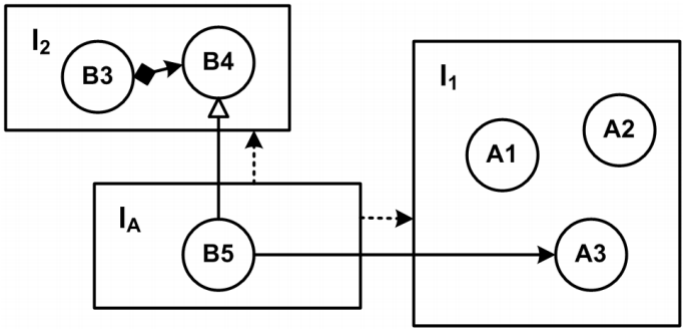


Example

Exten
ded C

Reuse



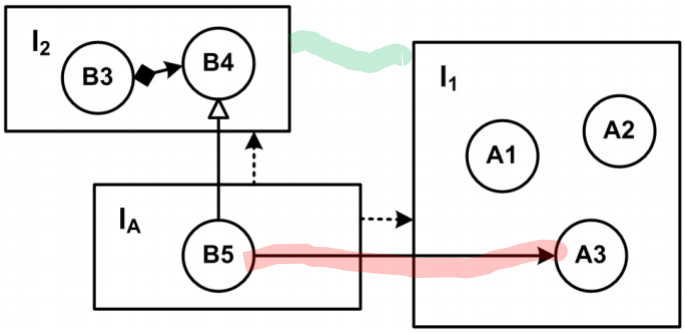


Reuse

languages dependencies	homogeneous	heterogeneous
independent	Reuse	Embedding
dependent	Referencing	Extension

fragment structure

Independent



No containment

Reuse

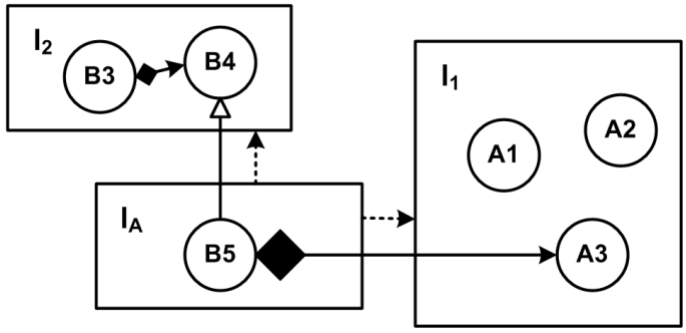
Often the referenced language is built expecting it will be reused.

Hooks may be added.

Embedding

languages dependencies	homogeneous	heterogeneous
independent	Reuse	**Embedding**
dependent	Referencing	Extension

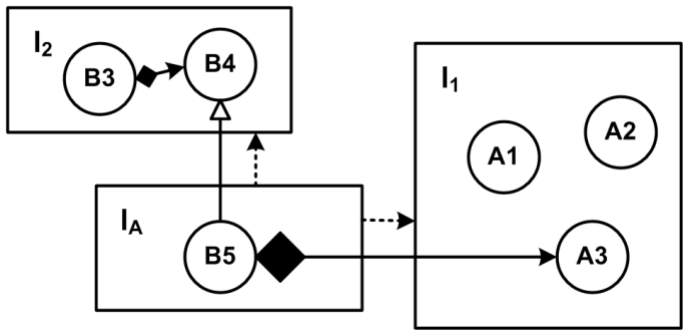
fragment structure



Embedding

languages dependencies	homogeneous	heterogeneous
independent	Reuse	**Embedding**
dependent	Referencing	Extension

fragment structure



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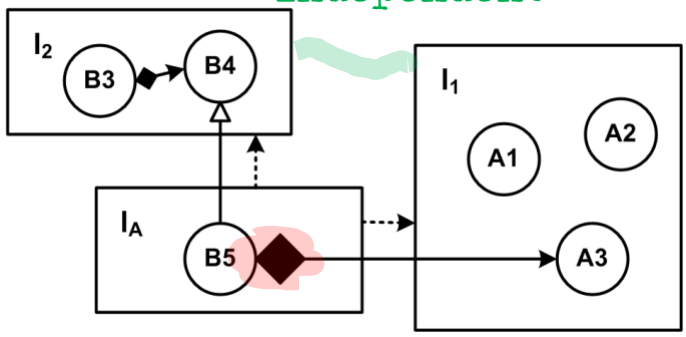
Embedding

languages dependencies	homogeneous	heterogeneous
independent	Reuse	Embedding
dependent	Referencing	Extension

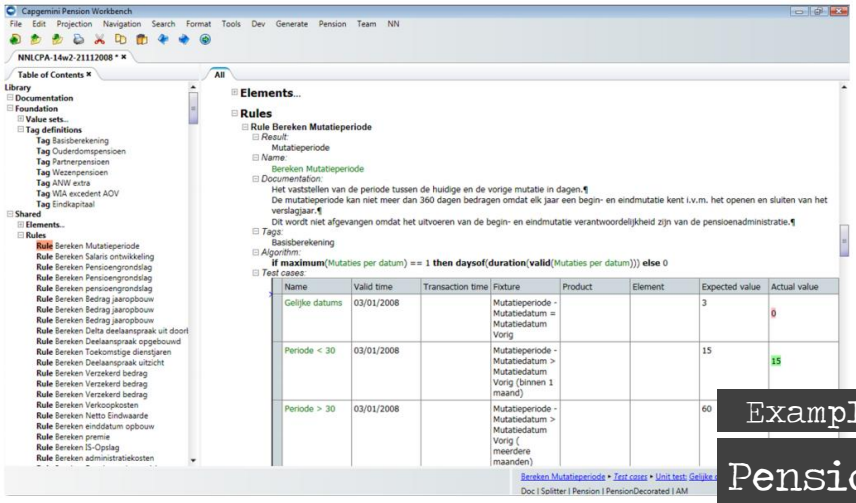
fragment structure

Independent



Containment

Embedding



Example

Pension Plans

Embedding

Embedding often uses Extension to extend the embedded language to adapt it to its new context.

Challenges - Syntax

Extension and Embedding requires modular concrete syntax

Many tools/formalisms cannot do that

Challenges - Type Systems

Extension: the type system of the base language must be designed to be extensible/ overridable

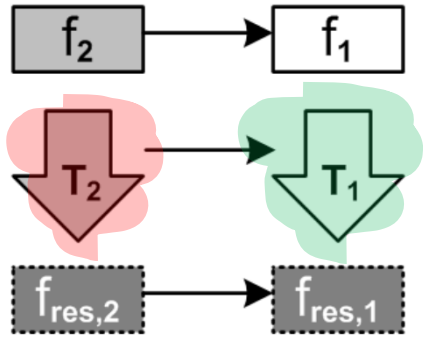
Challenges - Type Systems

Reuse and Embedding: Rules that affect the interplay can reside in the adapter language.

Challenges - Trafo & Gen

Referencing (I)

Written specifically for the combination



Can be Reused

Two separate, dependent single-source transformations

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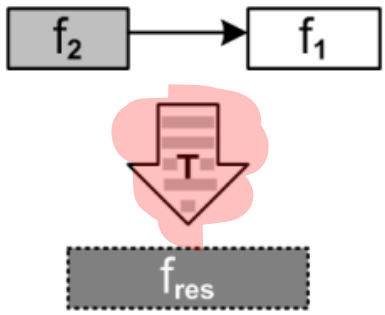
Challenges - Trafo & Gen

Referencing (II)



A single multi-sourced transformation

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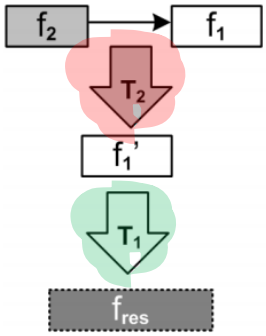
Challenges - Trafo & Gen

Referencing (III)



A preprocessing trafo that changes the referenced frag in a way specified by the referencing frag

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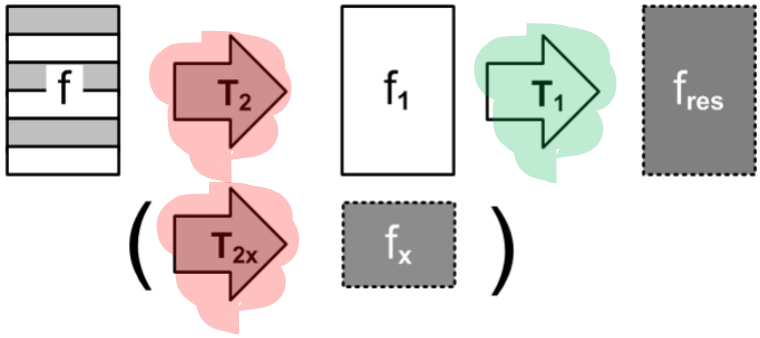
Challenges - Trafo & Gen

Extension



Transformation by assimiliation, i.e. generating code in the host lang from code expr in the extension lang.

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Challenges - Trafo & Gen

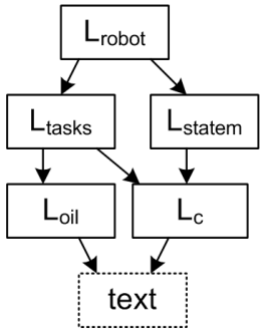
Extension

```
module impl imports <<imports>> {

  int speed( int val ) {
    return 2 * val;
  }

  robot script stopAndGo
    block main on bump
      accelerate to 12 + speed(12) within 3000
      drive on for 2000
      turn left for 200
      decelerate to 0  within 3000
      stop

}
```

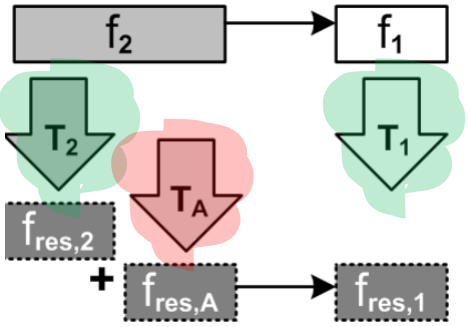


Example

Extended C

Challenges - Trafo & Gen

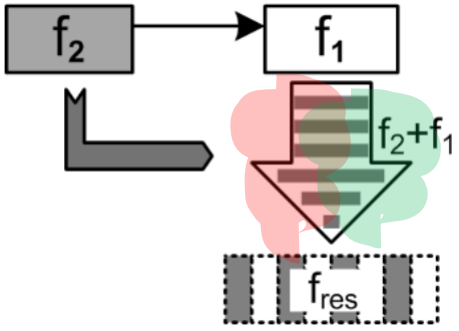
Reuse (I)



Reuse of existing transformations for both fragments plus generation of adapter code

Challenges - Trafo & Gen

Reuse (II)



composing transformations

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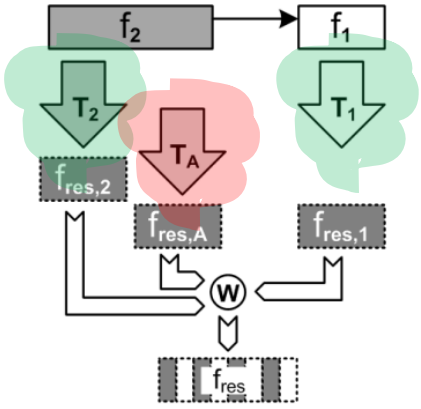
Challenges - Trafo & Gen

Reuse (III)



generating separate artifacts
plus a weaving specification

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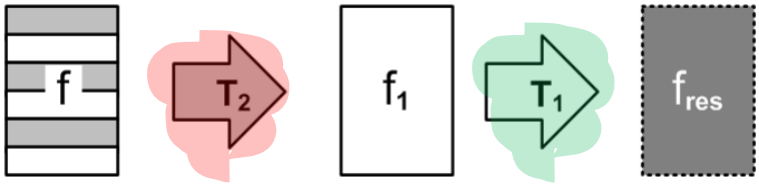
Challenges - Trafo & Gen

Embedding (I)

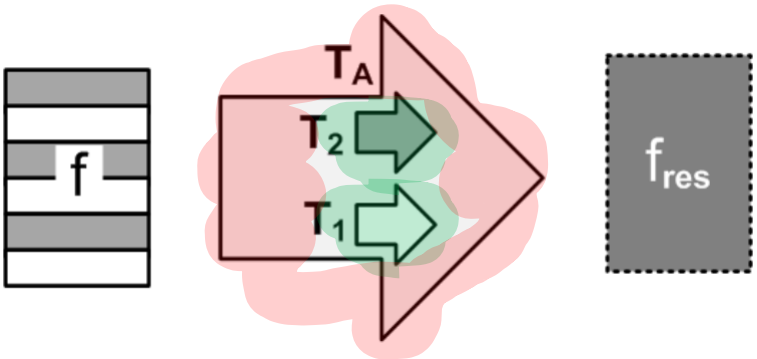
a purely embeddable language may not come with a generator.



Assimilation (as with Extension)

Challenges - Trafo & Gen

Embedding (II)



Adapter language can coordinate the transformations for the host and for the emebedded languages.

Concrete Syntax

expressivity	completeness
coverage	paradigms
semantics	modularity
separation of concerns	concrete syntax

process

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UI for the language!

Important for acceptance by users!

- Textual
- Symbolic
- Tabular
- Graphical

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Reuse existing syntax of domain, if any!

Tools let you freely combine all kinds.

Default: Text

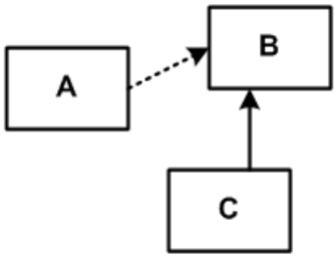
Editors simple to build
Productive
Easy to integrate w/ tools
Easy to evolve programs

… then add other forms, if really necessary

Default: Text

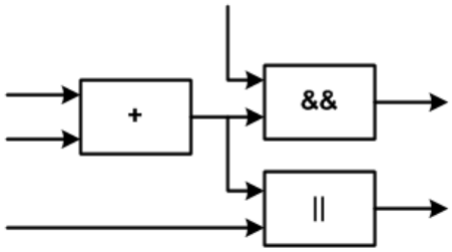
Editors simple to build
Productive
Easy to integrate w/ tools
Easy to evolve programs

Graphical in case…



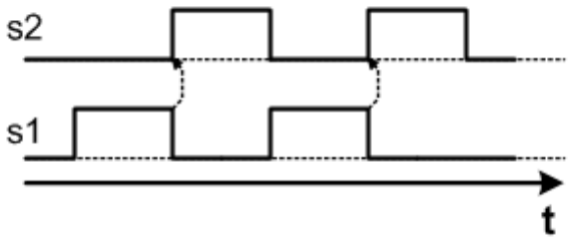
Relationships

Graphical in case…



Flow and
Depenency

Graphical in case…



Causality
and Timing

Symbolic

Either Mathematical, or often highly inspired by domain

¤ *3.3 Commutatiegetallen op 1 leven¶*

$$D_x = v^x \cdot \frac{l_x}{100}$$ ¤6 Dec(3)¶

Implemented in ¤ V9401¶

¶

$$N_x = \sum_{t=0}^{\omega - x} D_{x+t}$$ ¤7 Dec(3)

¶

¤ *3.6 Contante waarde 1 leven/ 2 levens¶*

$$E_{n\,x} = \frac{D_{x+n}}{D_x}$$ ¤19 Dec(4)

¶

$$a_x = \ddot{a}_x - 1$$ ¤21 Dec(3)

¶

$$\bar{a}_x = \ddot{a}_x - 0{,}5$$ ¤22 Dec(3)

¶

$$\ddot{a}_{x\overline{n}|} = \frac{N_x - N_{x+n}}{D_x}$$ ¤23 Dec(3)

$$\bar{a}_{x\overline{n}|} = \ddot{a}_{x\overline{n}|} - 0{,}5 + 0{,}5 \cdot {}_nE_x$$ ¤25 Dec(3)

¶

Tables

Name	Documentation	Tags	Valid time	Transaction time	Fixture	Product	Element	Expected value	Actual value
Accrued right at retireme			2006-12-31	2007-9-24	Jan De Jong	Old Age Pension	Accrued right	761.0402	761.0402
Accrued Right last final pay			2004-1-1	2007-9-24	Jan De Jong	Old Age Pension	Accrued right	705.0589	705.0589
premium last year			2006-1-1	2007-9-24	Jan De Jong	Old Age Pension	Premium old age pension	329.0625	329.0625
Accrued right at retireme 2)			2006-12-31	2007-9-24	Piet Van Dijk	Old Age Pension	Accrued right	740.94	724.7658
			1985-12-31	2007-9-24	Jan De Jong	Old Age Pension	Accrued Right in service period	73.661	73.661
			1985-12-31	2007-9-24	Jan De Jong	Old Age Pension	Years of service in service period	3.7534	3.7534
			1987-12-31	2007-9-24	Jan De Jong	Old Age Pension	Pension base average FP	7750	7750
			1998-12-31	2007-9-24	Jan De Jong	Old Age Pension	Accrued Right in service period	387.7449	387.7449
			1998-12-31	2007-9-24	Jan De Jong	Old Age Pension	Years of service in service period	10.8082	10.8082
			1998-12-31	2007-9-24	Jan De Jong	Old Age Pension	Pension base average FP	8250	8250

Combinations

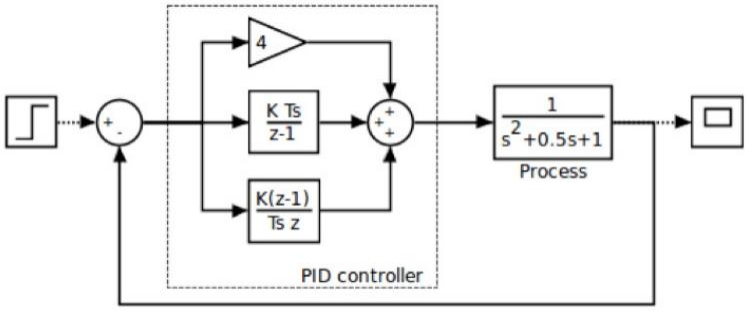
```
c/s interface Decider {
  int decide(int x, int y) pre
}

component AComp extends nothing {
  ports:
    provides Decider decider
  contents:
    int decide(int x, int y) <- op decider.decide {
      return int, 0
```

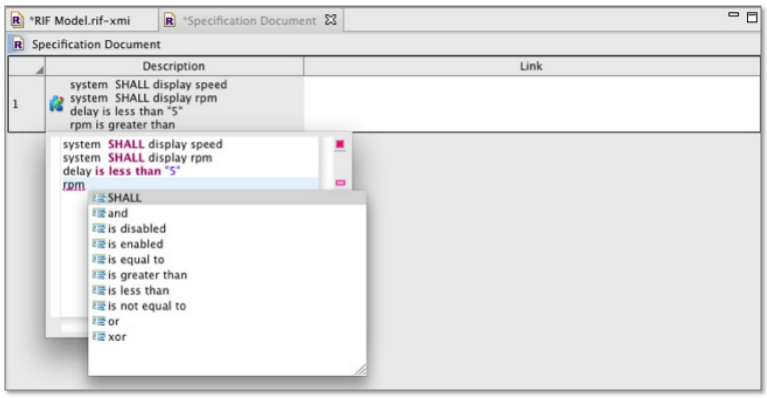
	x == 0	x > 0
y == 0	0	1
y > 0	1	2

```
    }
}
```

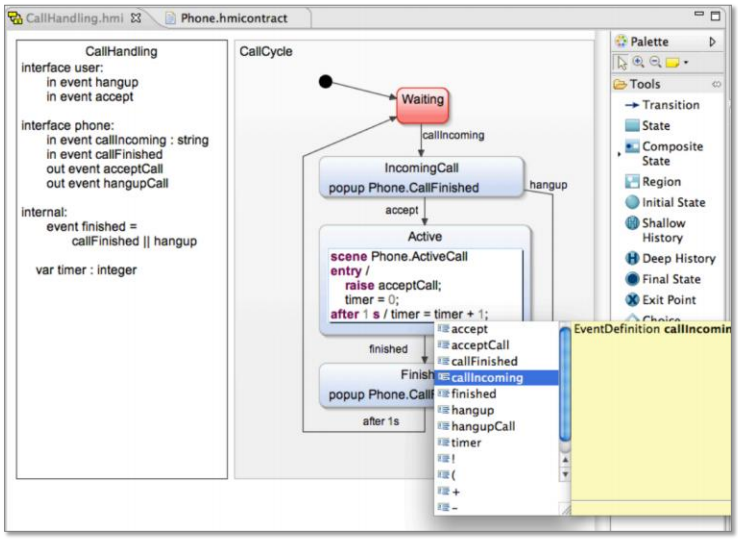

Combinations



Combinations



Combinations

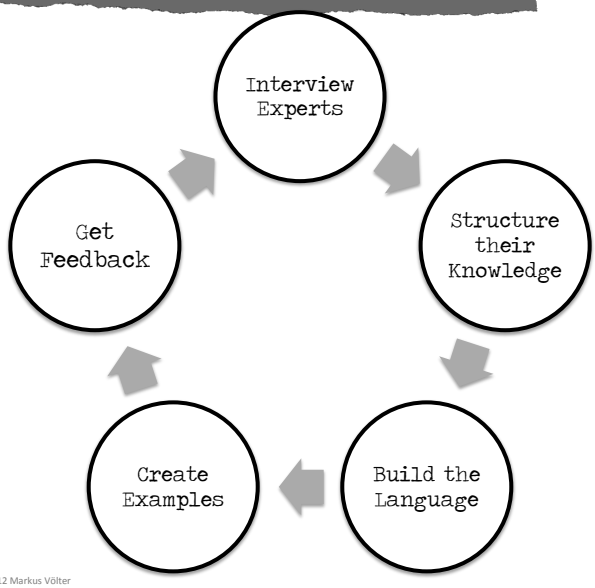


Process

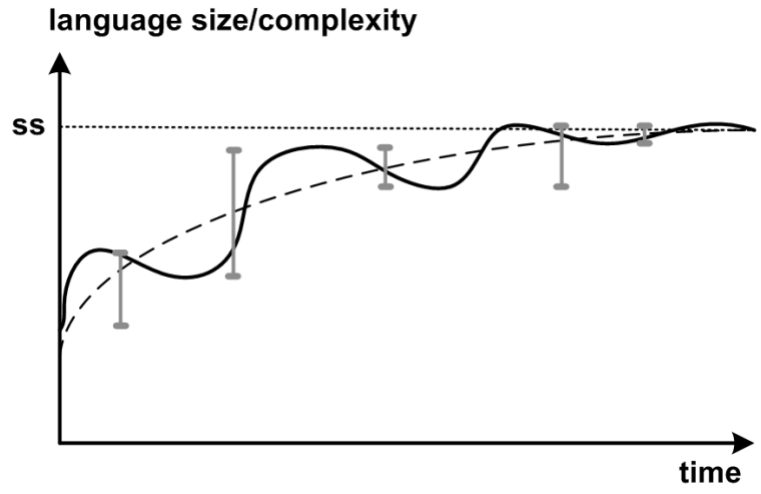
expressivity	completeness
coverage	paradigms
semantics	modularity
separation of concerns	concrete syntax

process

Domain Analysis



Iterate to goal



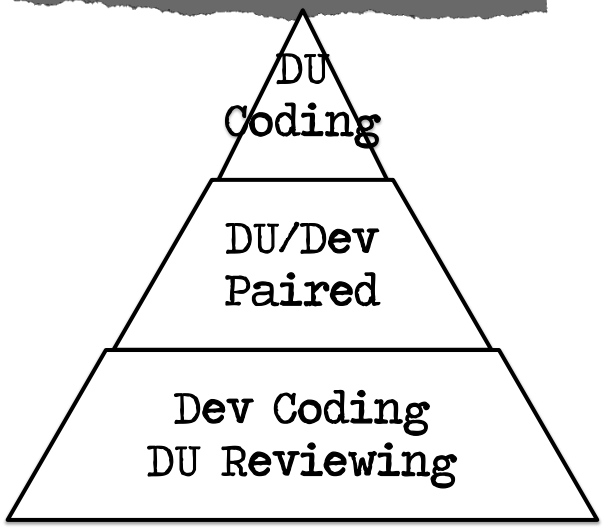
Documentation

Create example-based tutorials!

Domain Folks Programming?

Precision vs. Algorithmics!

Domain Folks Programming?



DSL as a Product

Release Plan
Bug Tracker
Testing!
Support
Documentation

Reviews

Reviews become easier --- less code, more domain-specific

The End.

This material is part of my upcoming (early 2013) book **DSL Engineering**. Stay in touch, it may become a free eBook ☺

voelter.de/dslbook

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voelterblog.blogspot.de
@markusvoelter
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