DSL Design

A conceptual framework for building good DSLs

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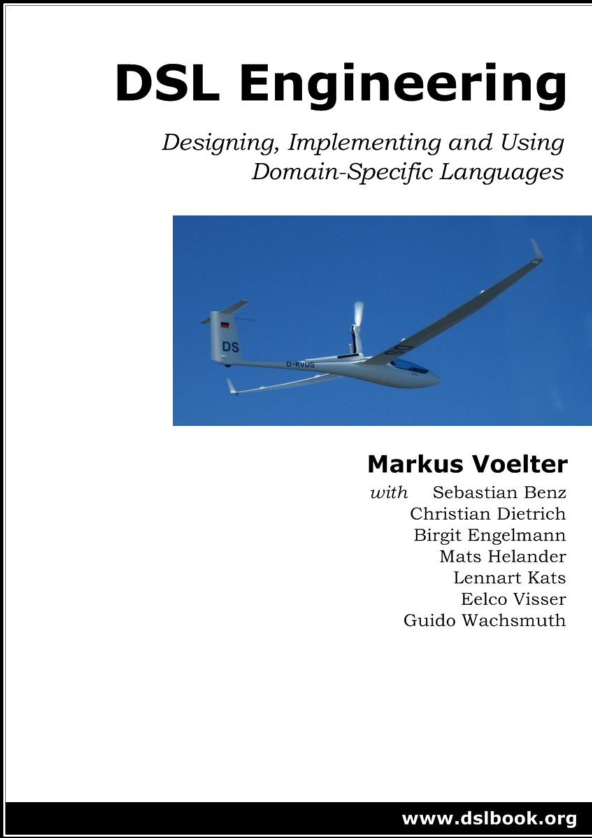


This material is part of my upcoming (Feb. 2013) book

DSL Engineering

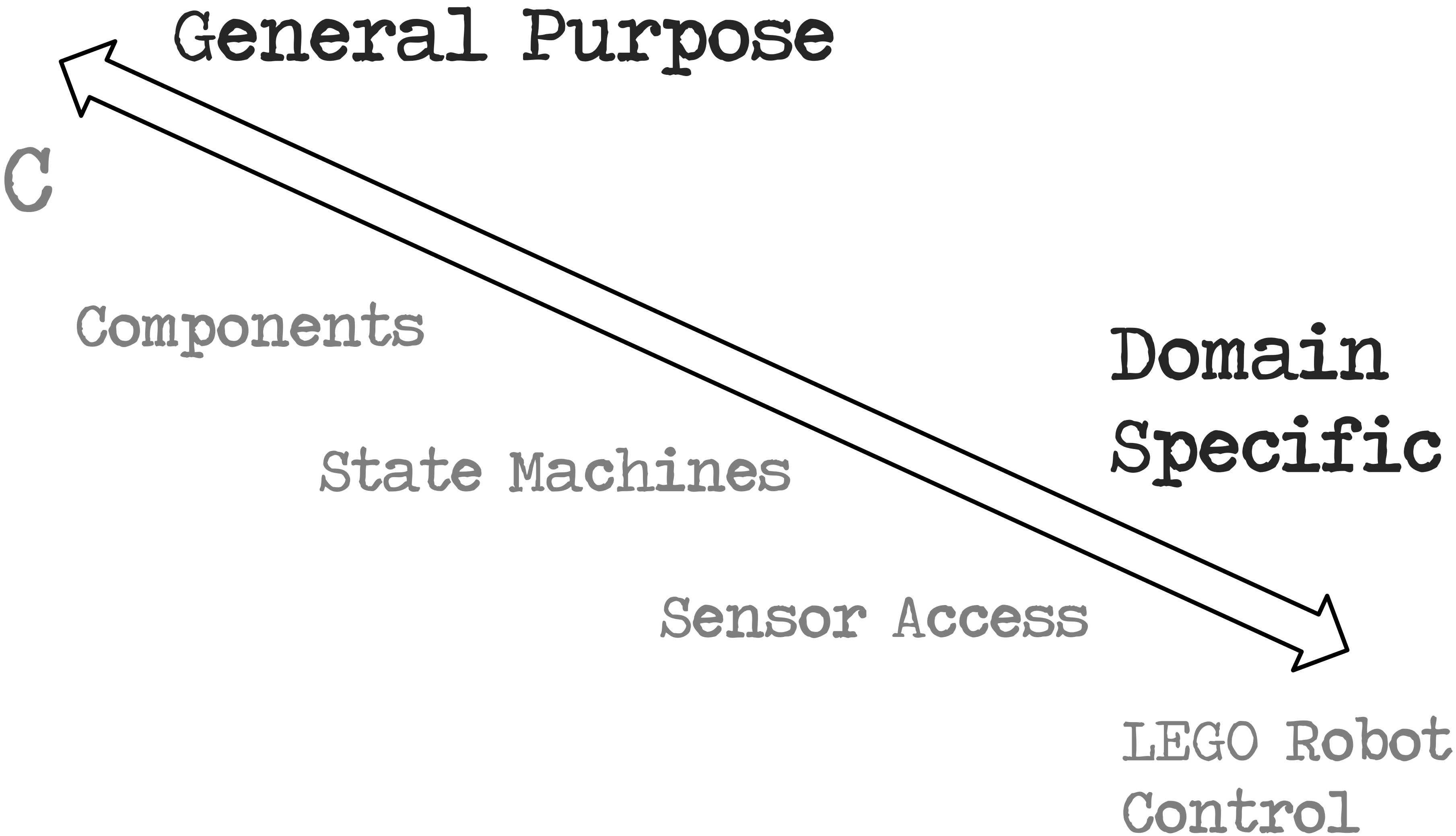
Designing, Implementing and Using Domain-Specific Laguages

Stay in touch; it will be cheap :-)

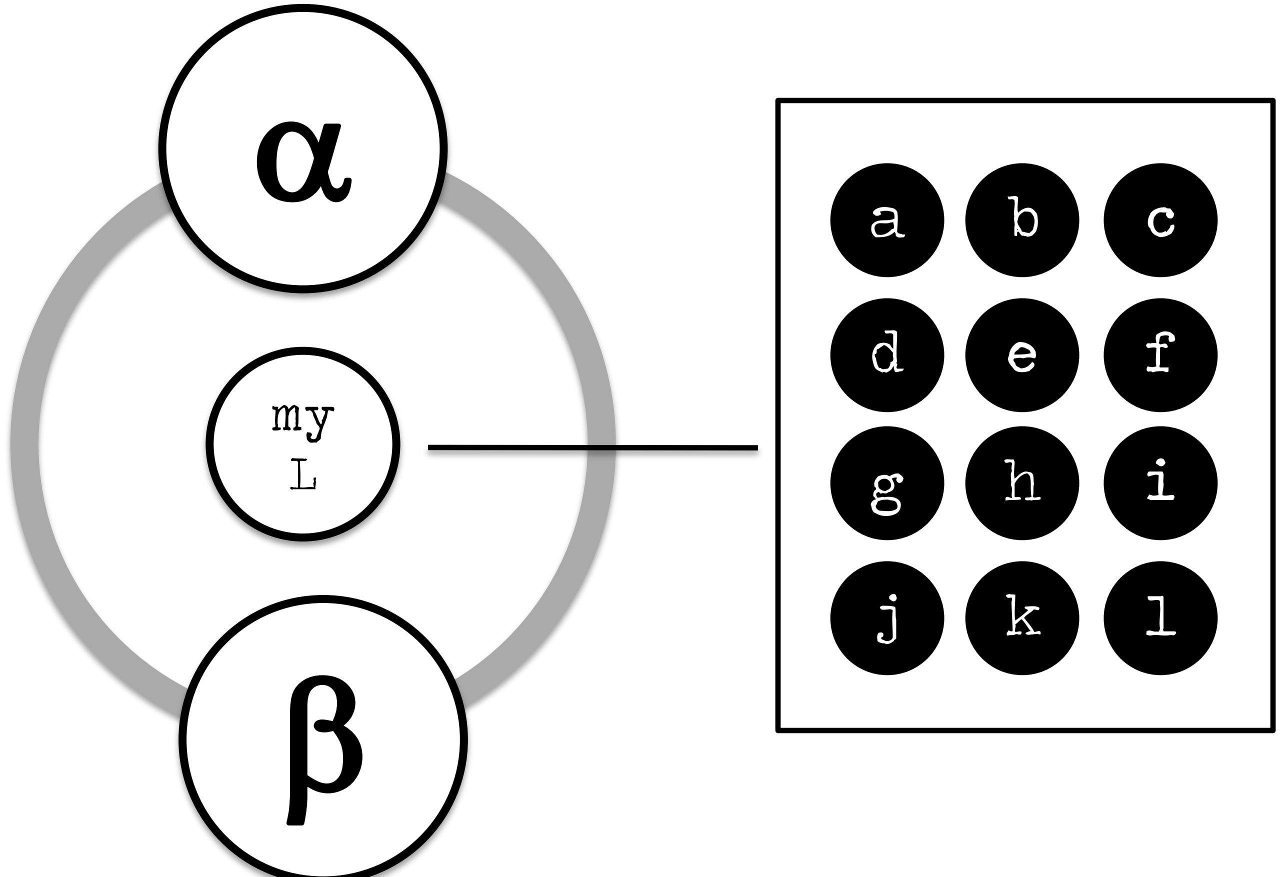
http://dslbook.org

Introduction

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.


General Purpose
C
Components
State Machines
Domain
Specific
Sensor Access
LEGO Robot
Control

Modular Language



with many optional, composable modules

Case Studies

```
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

Compo
nents

```
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

```
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

Refrige
rators

```
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

Refrige
rators

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

var tuerNachlaufSchwelle: int = 0

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        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

Refrigerators

```
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
  }

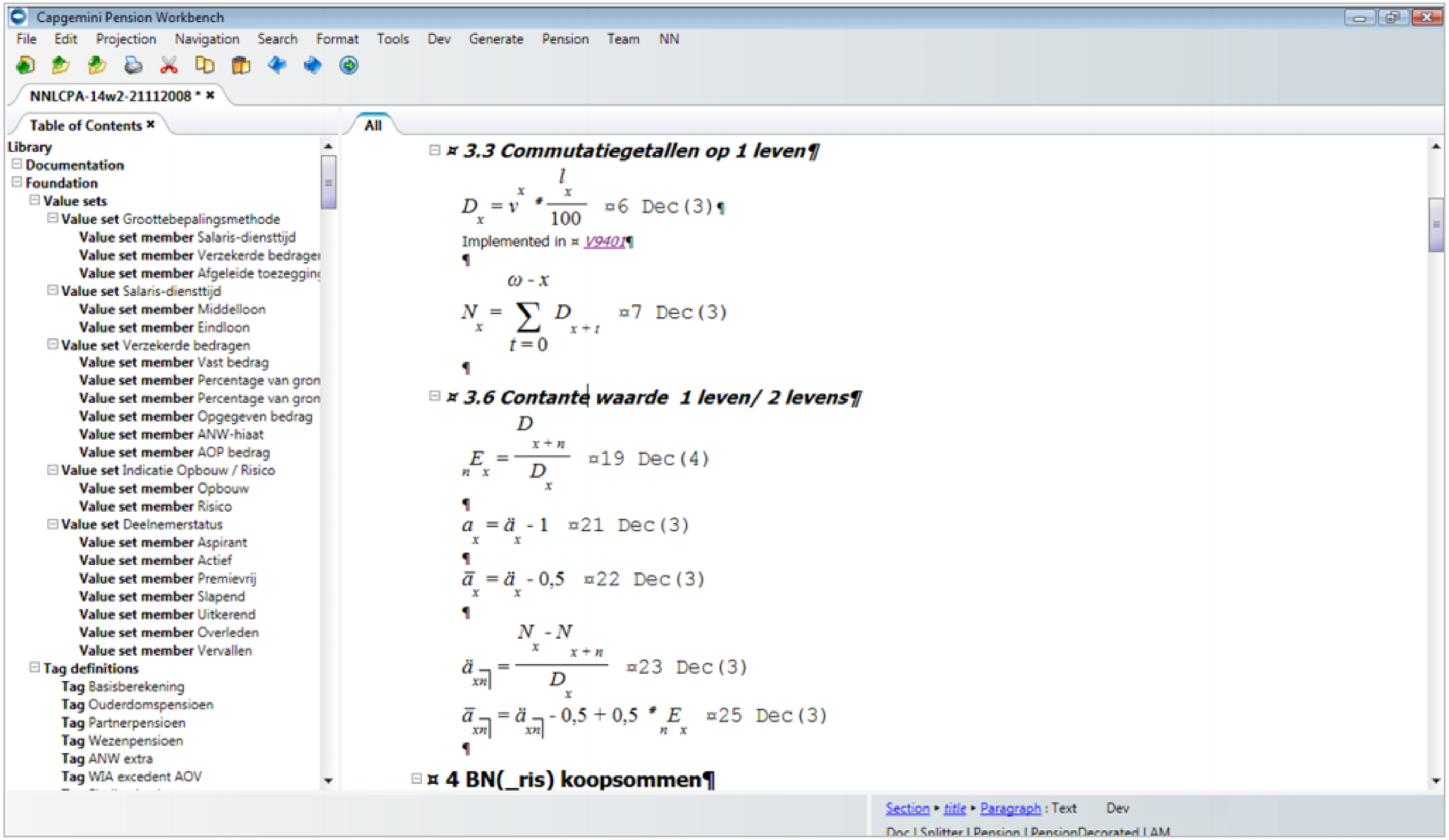
  terminate {
    ecrobot_set_light_sensor_inactive
              (SENSOR_PORT_T::NXT_PORT_S1);
```

```
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);
}
```

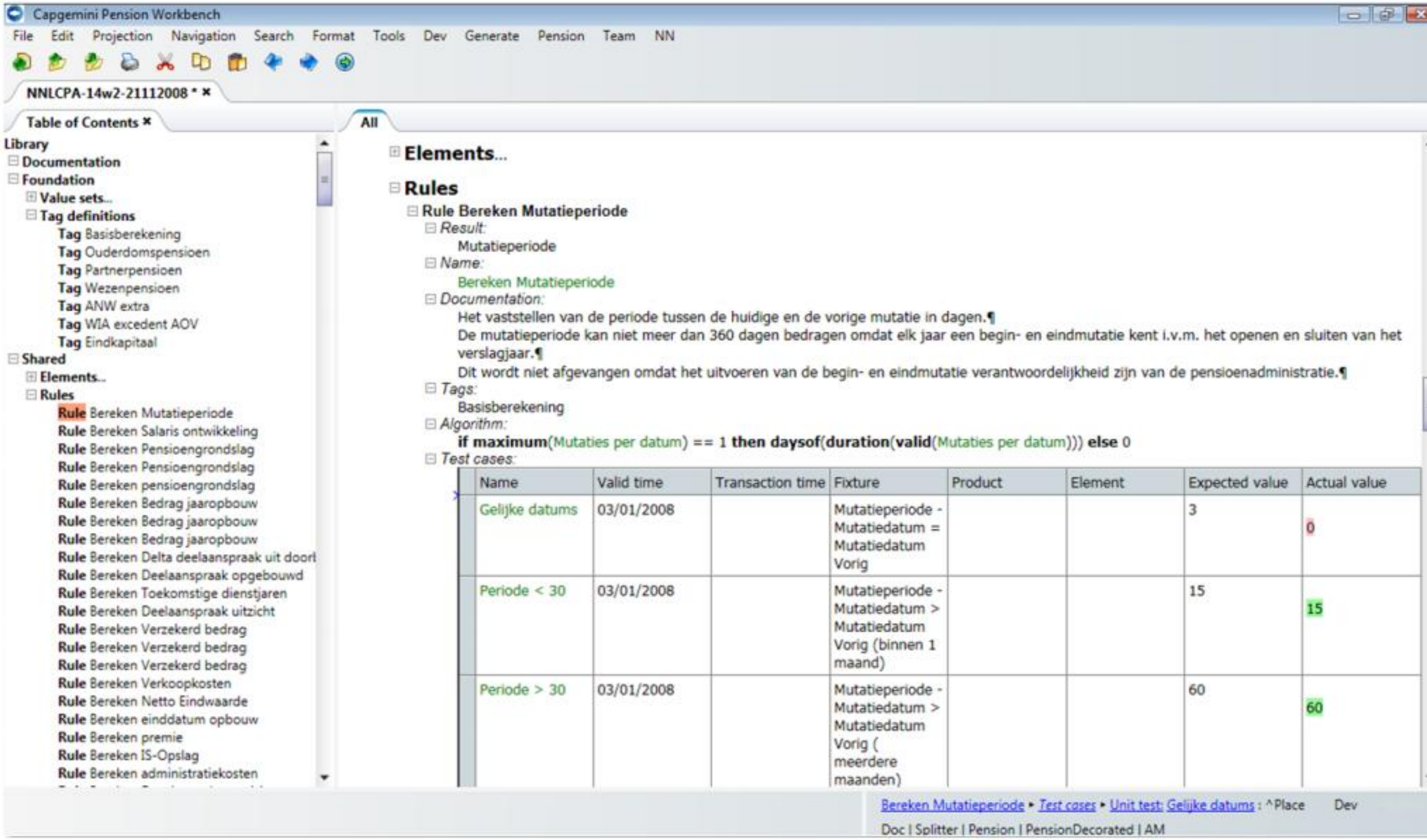
Example

Extended 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

Domain

body of knowledge in the real world

deductive
top down

Domain

Example

Penion Plans

Example

Refrige
rators

Domain

existing
software
(family)

inductive
bottom up

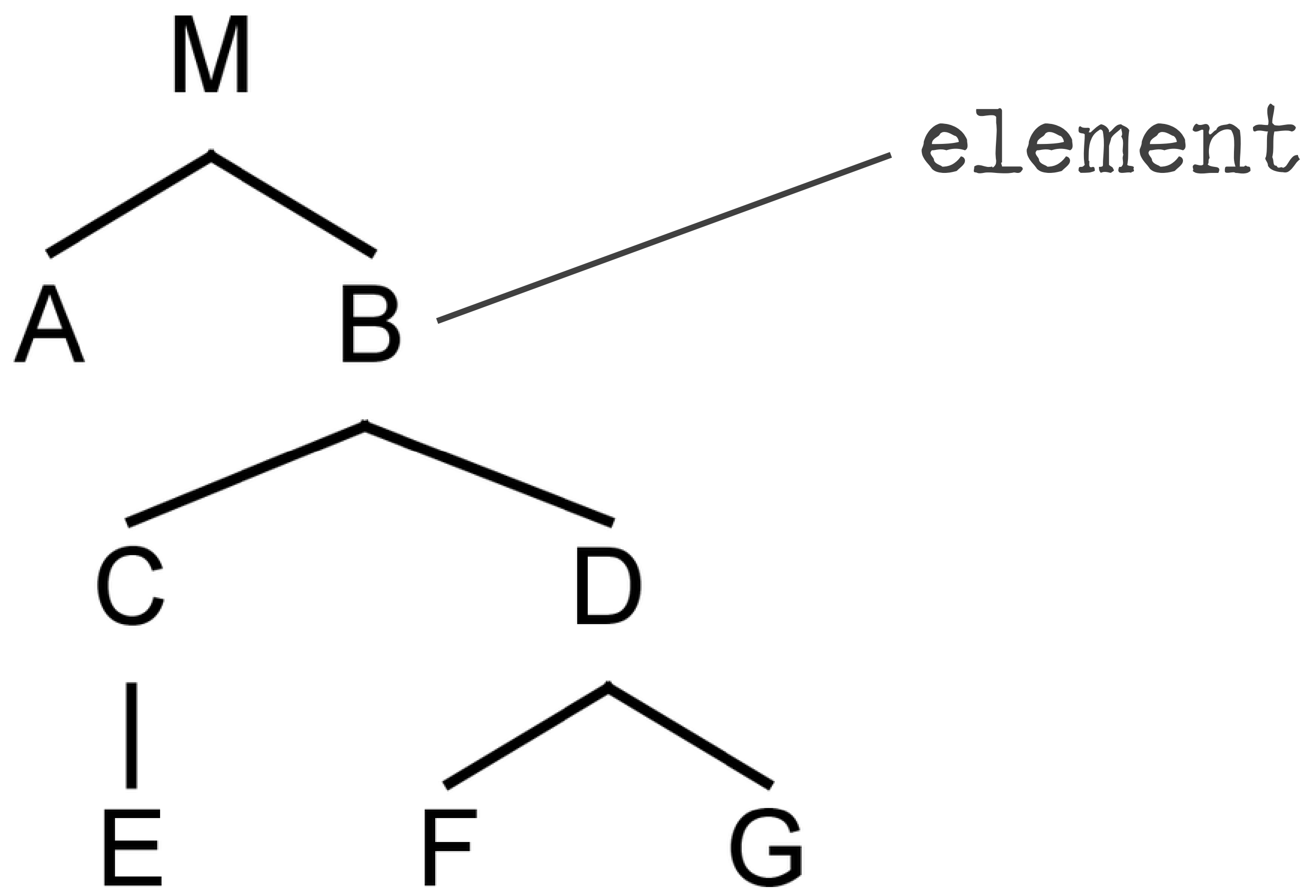
Example

Exten
ded C

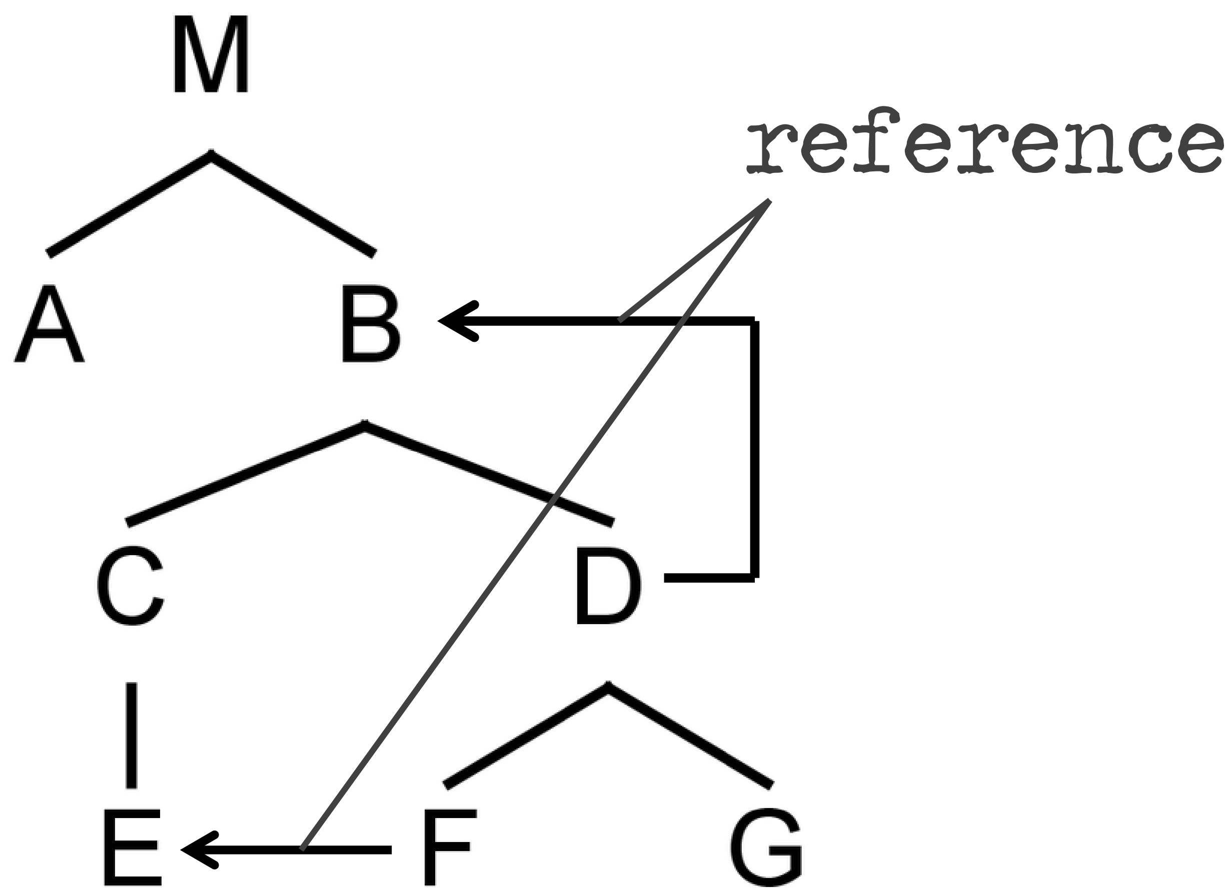
Example

Compo
netns

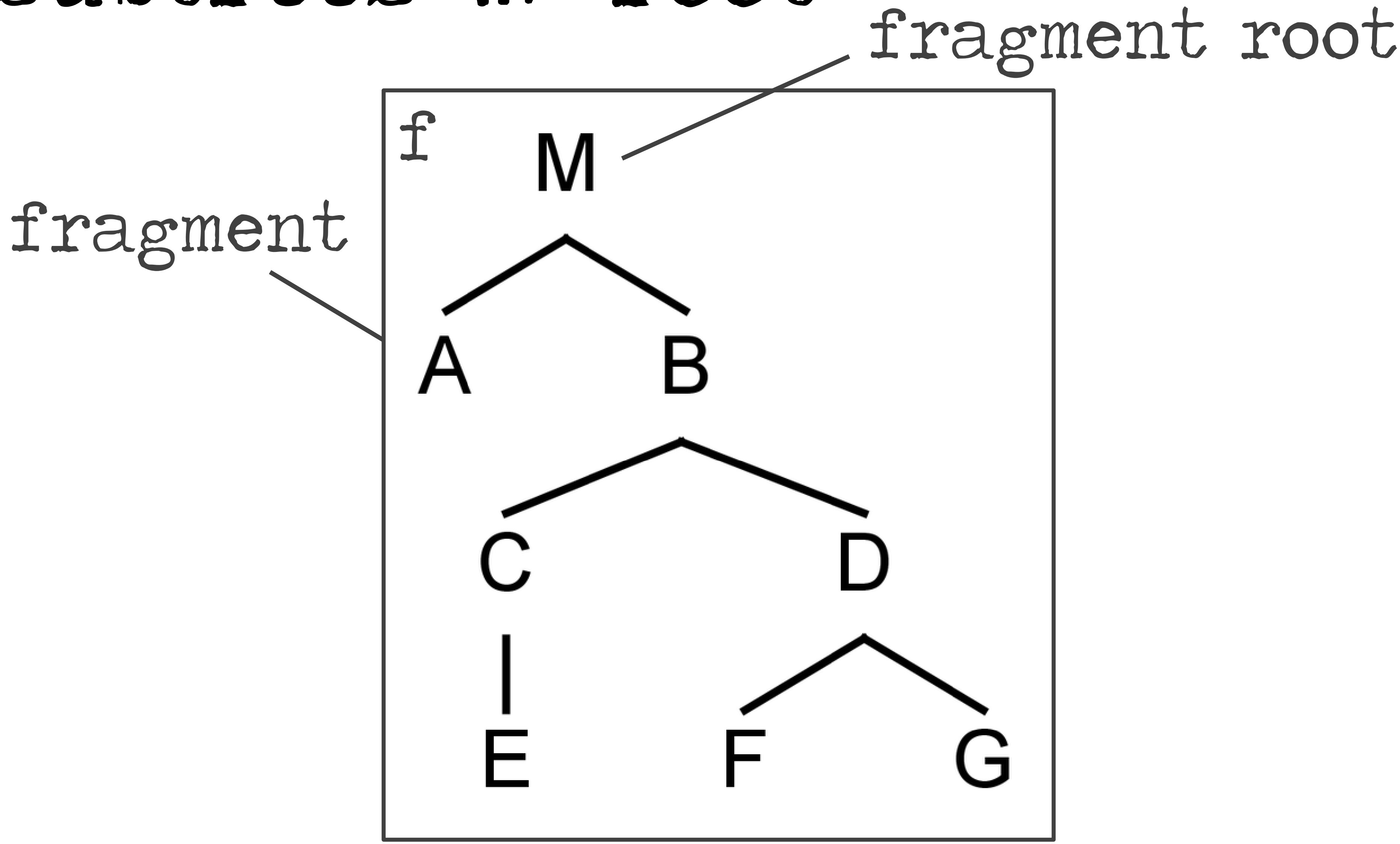
Programs are trees



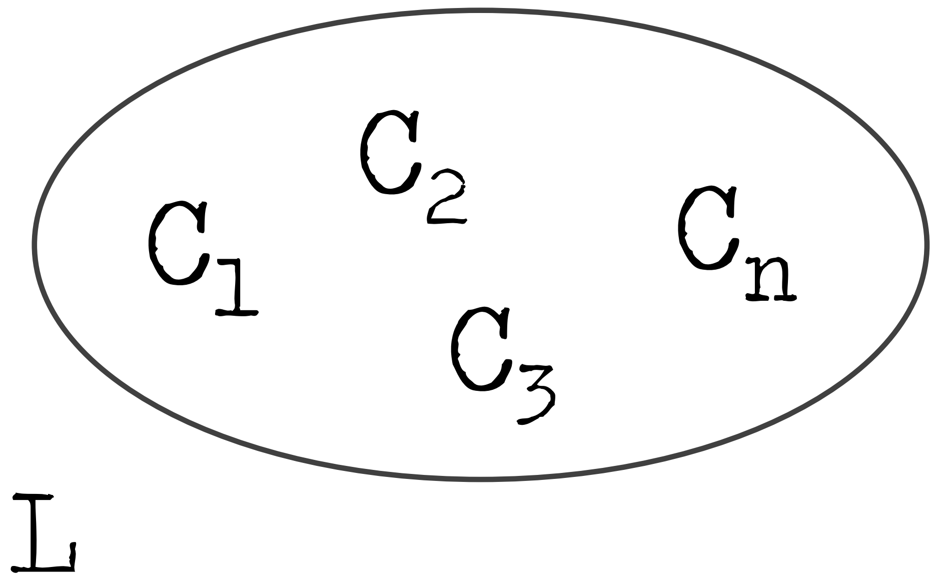
Programs are graphs, really.



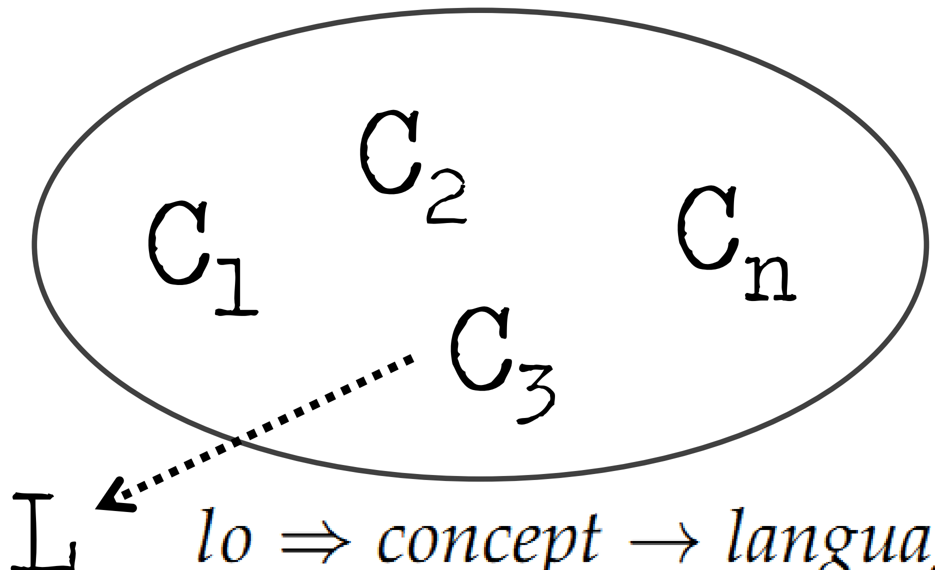
Fragments are subtrees w/ root



Languages are sets of concepts

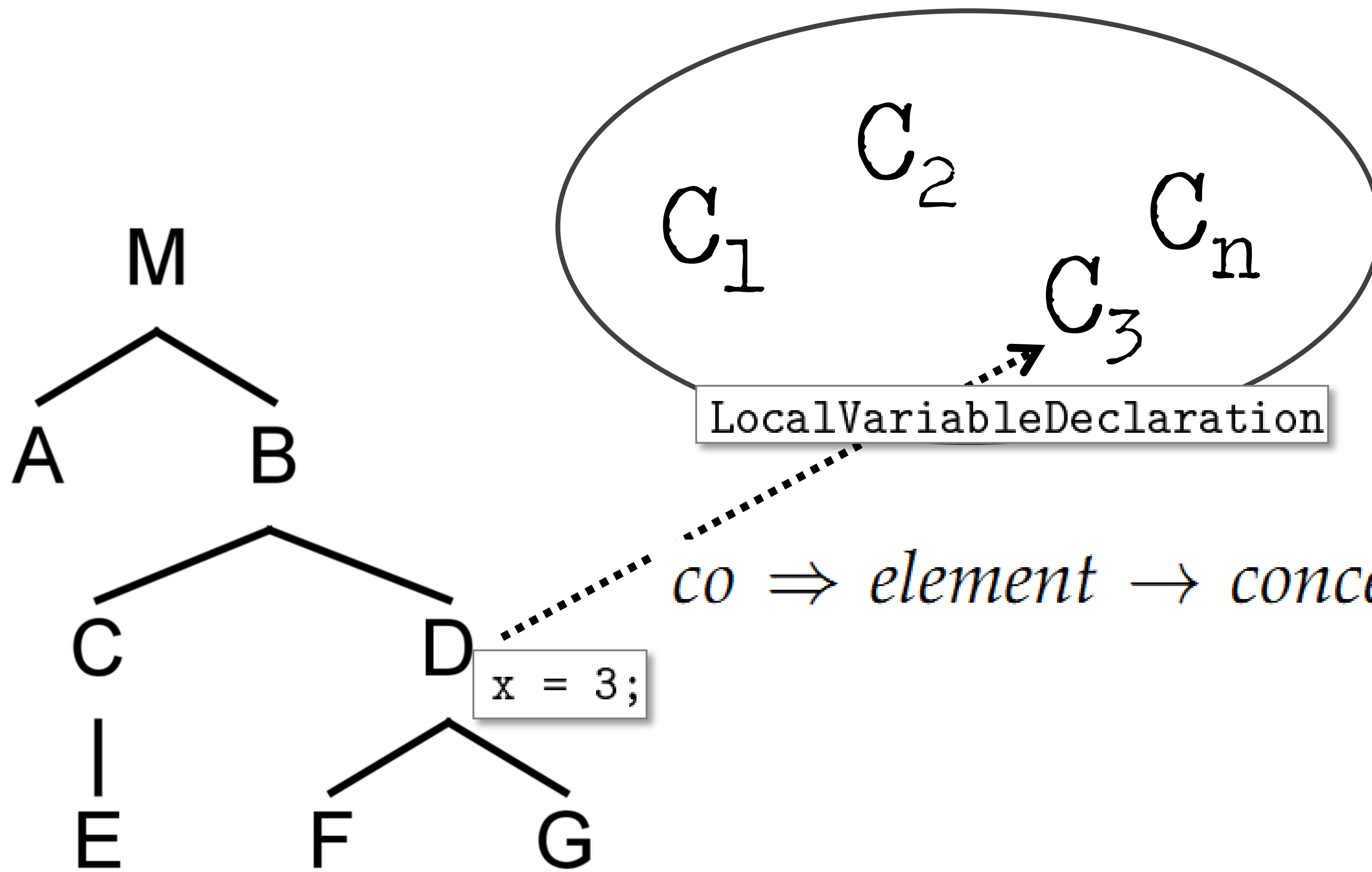


Languages are sets of concepts



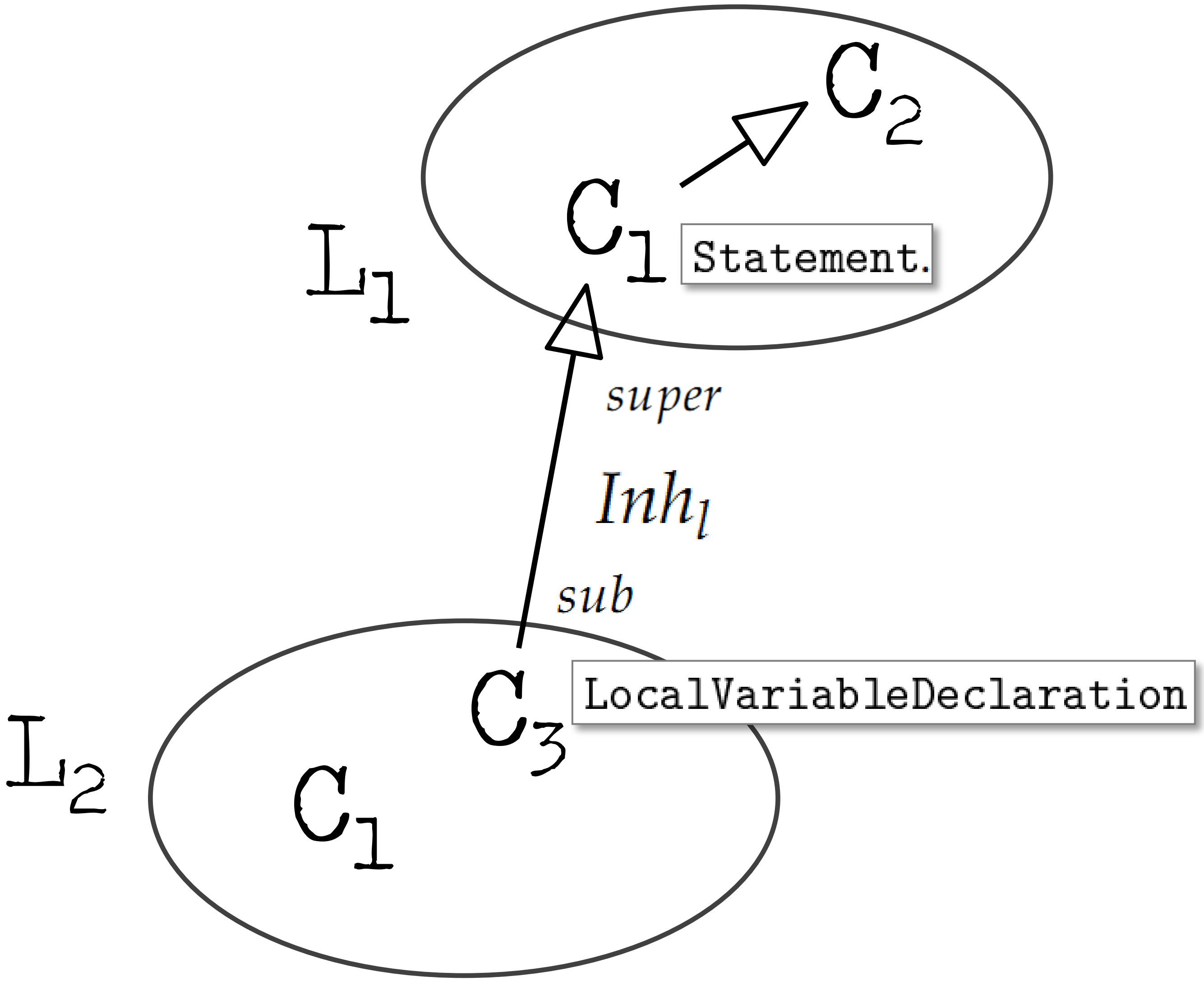
lo $\Rightarrow$ *concept* $\rightarrow$ *language*

Programs and languages



$co \Rightarrow element \rightarrow concept$

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

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

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

```
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)
}
```

Heterogeneous

C

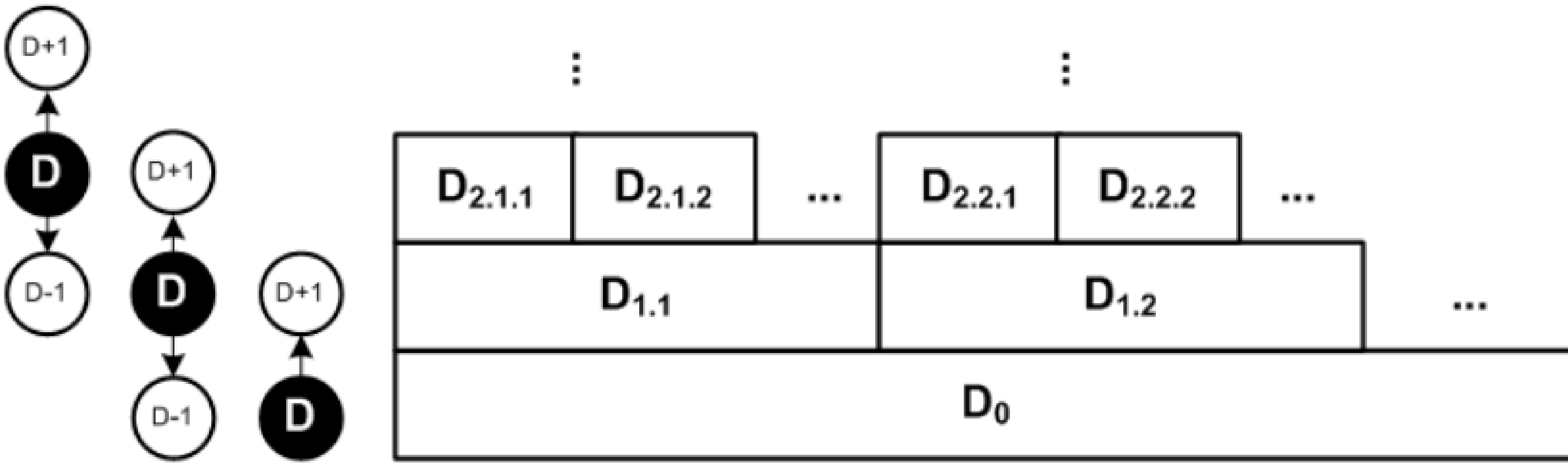
Statemachines

Testing

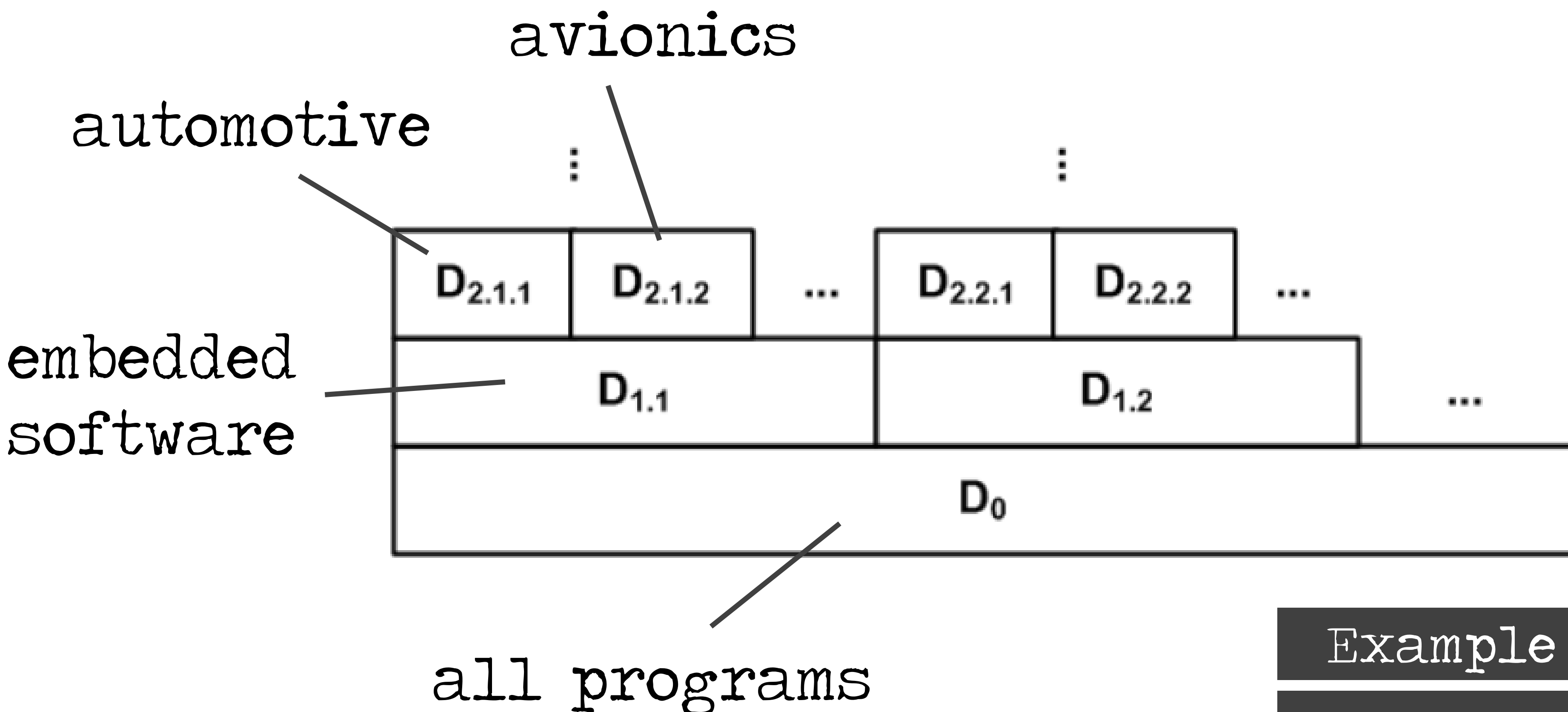
Example

Extended C

Domain Hierarchy



Domain Hierarchy



Example

Exten ded C

Design Dimensions

expressivity
coverage
semantics
separation of concerns

completeness
paradigms
modularity
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

Smaller Domain

More Specialized Language

Shorter Programs

The do-what-I-want language

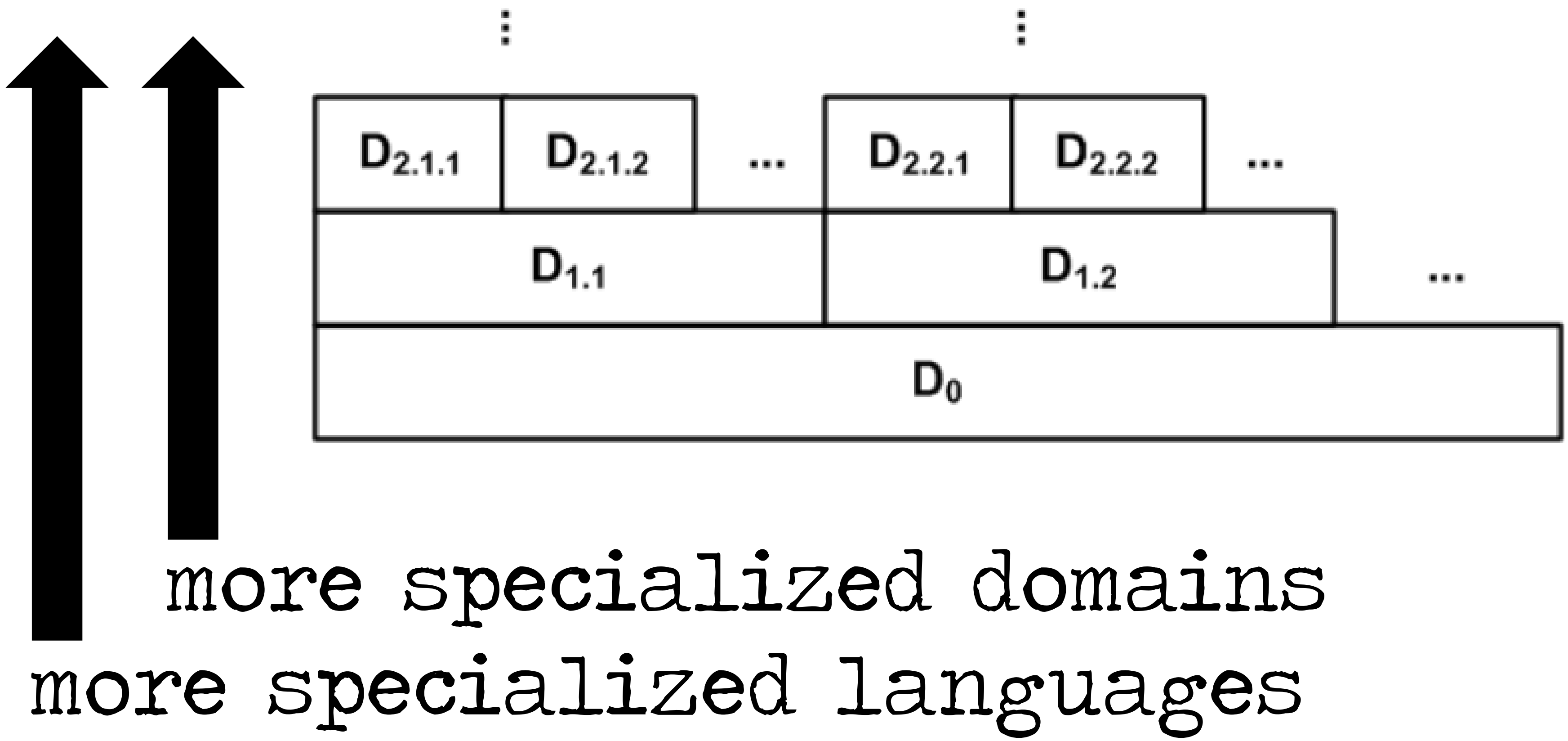
Ψ

Single Program vs. Class/Domain

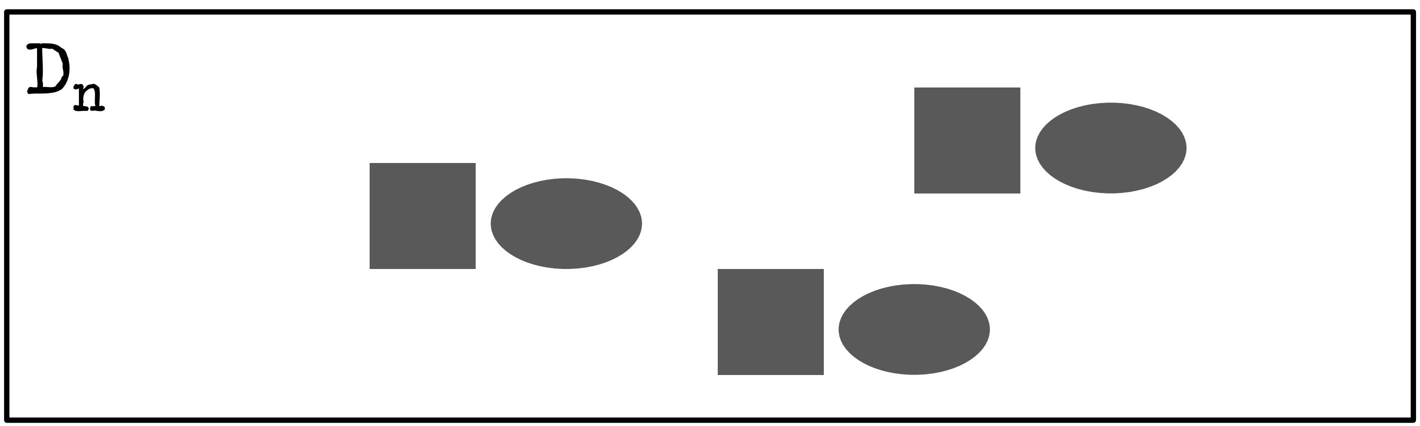
No Variability!

$$\Psi$$

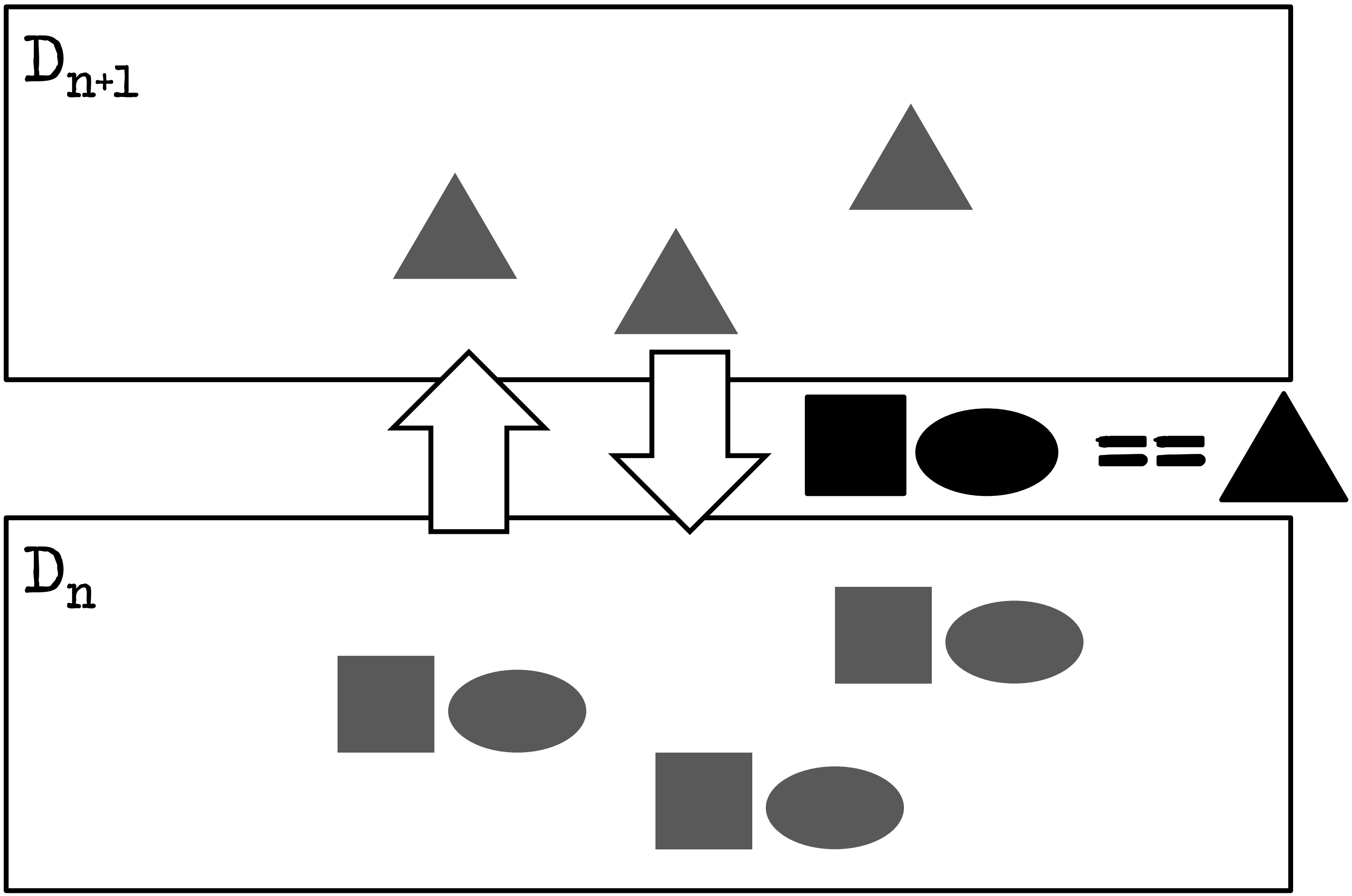
Domain Hierarchy



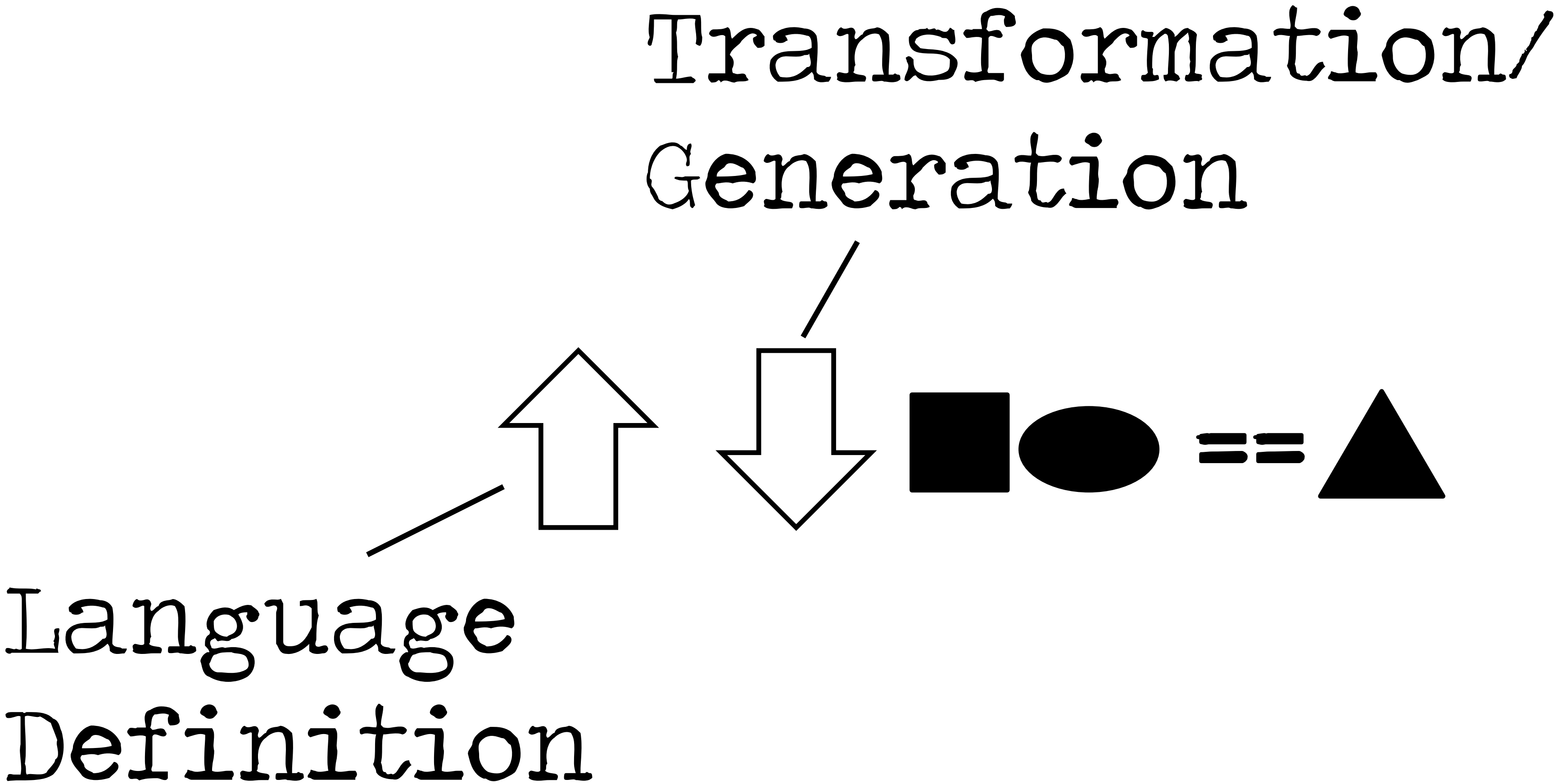
Reification



Reification



Reification



```
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] );
}
```

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!

Semantics & Execution

expressivity	completeness
coverage	paradigms
semantics	modularity
separation of concerns	concrete syntax

process

Static Semantics

Execution Semantics

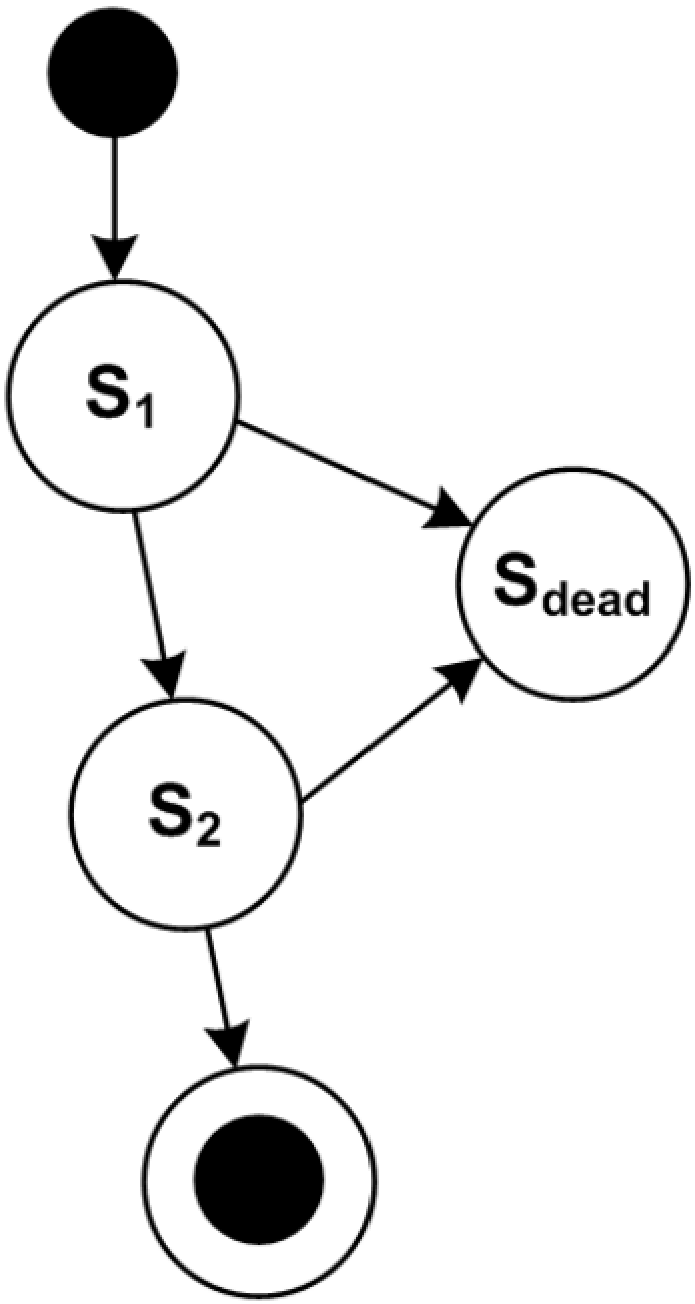
Static Semantics

Execution Semantics

Static Semantics

Constraints

Type Systems



Unique State Names

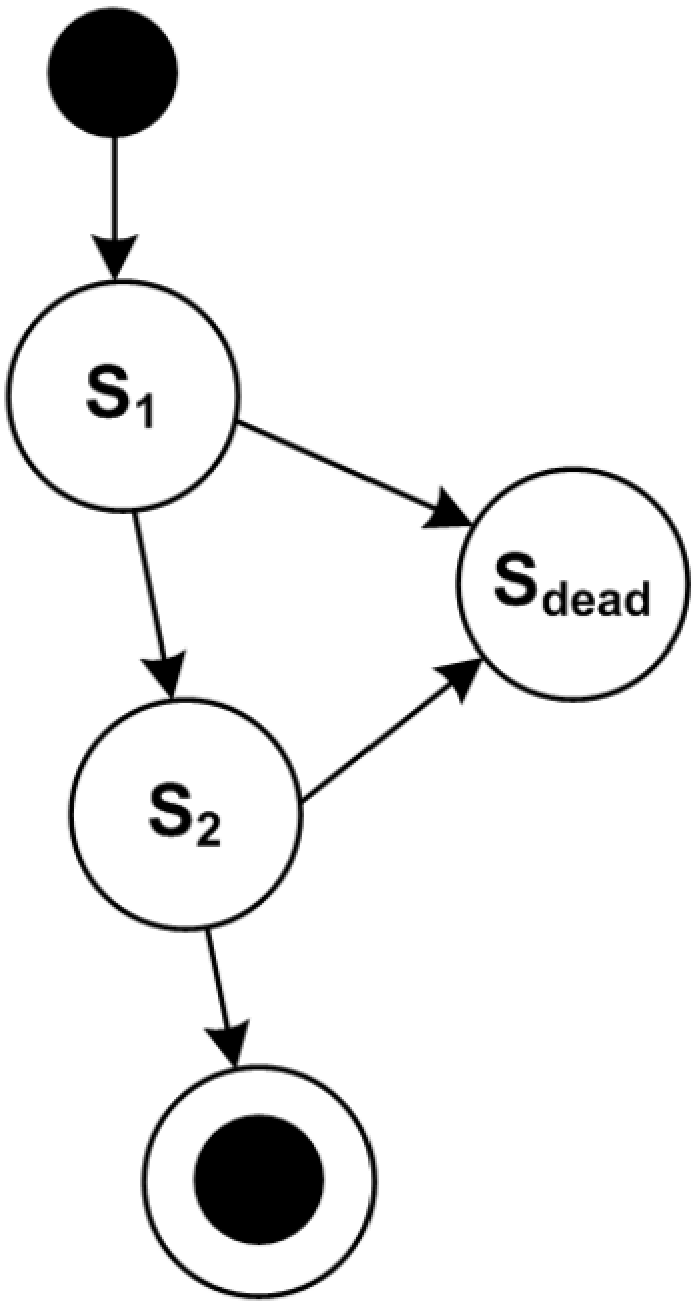
Unreachable States

Dead End States

...

Example

Extended C



Unique State Names

Unreachable States

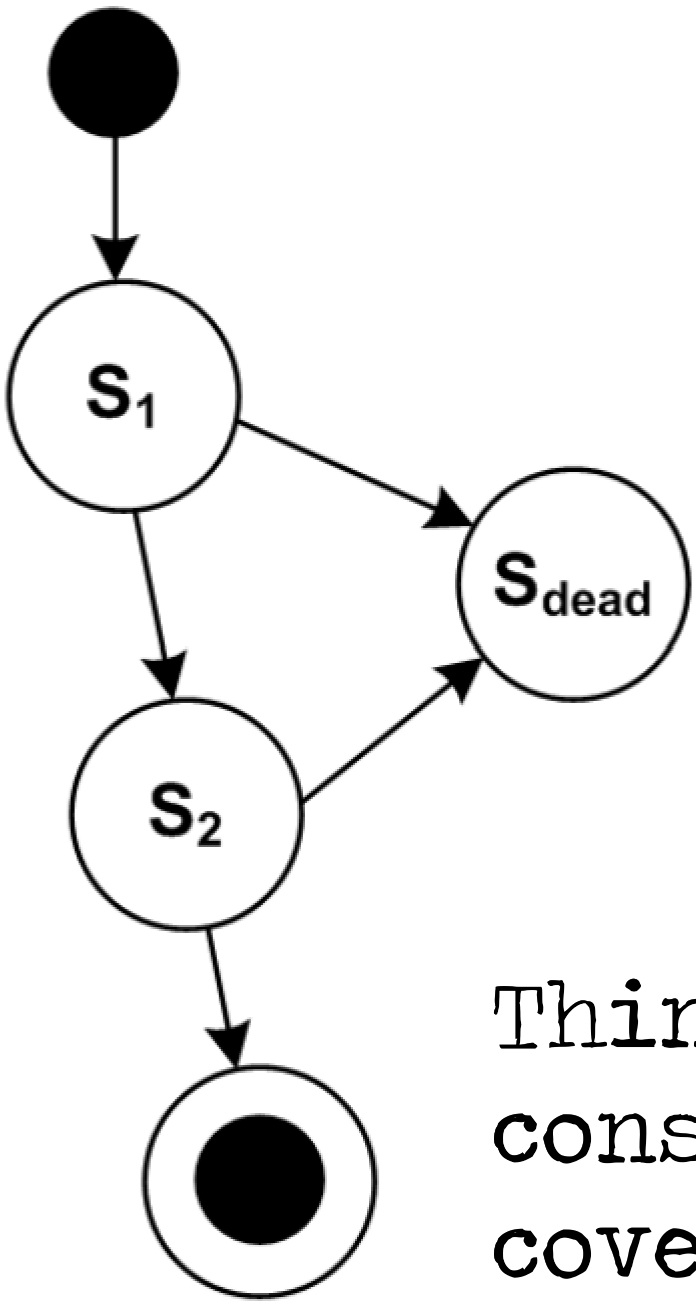
Dead End States

...

Easier to do on a declarative Level!

Example

Extended 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

Extended 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

Derive

Intent + Check	Derive
`var int x = 2 * someFunction(sqrt(2));`	
More code	
Better error messages	
Better Performance	

Intent + Check

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

More code

Better error messages

Better Performance

Derive

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

More convenient

More complex checkers

Harder to understand for users

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

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

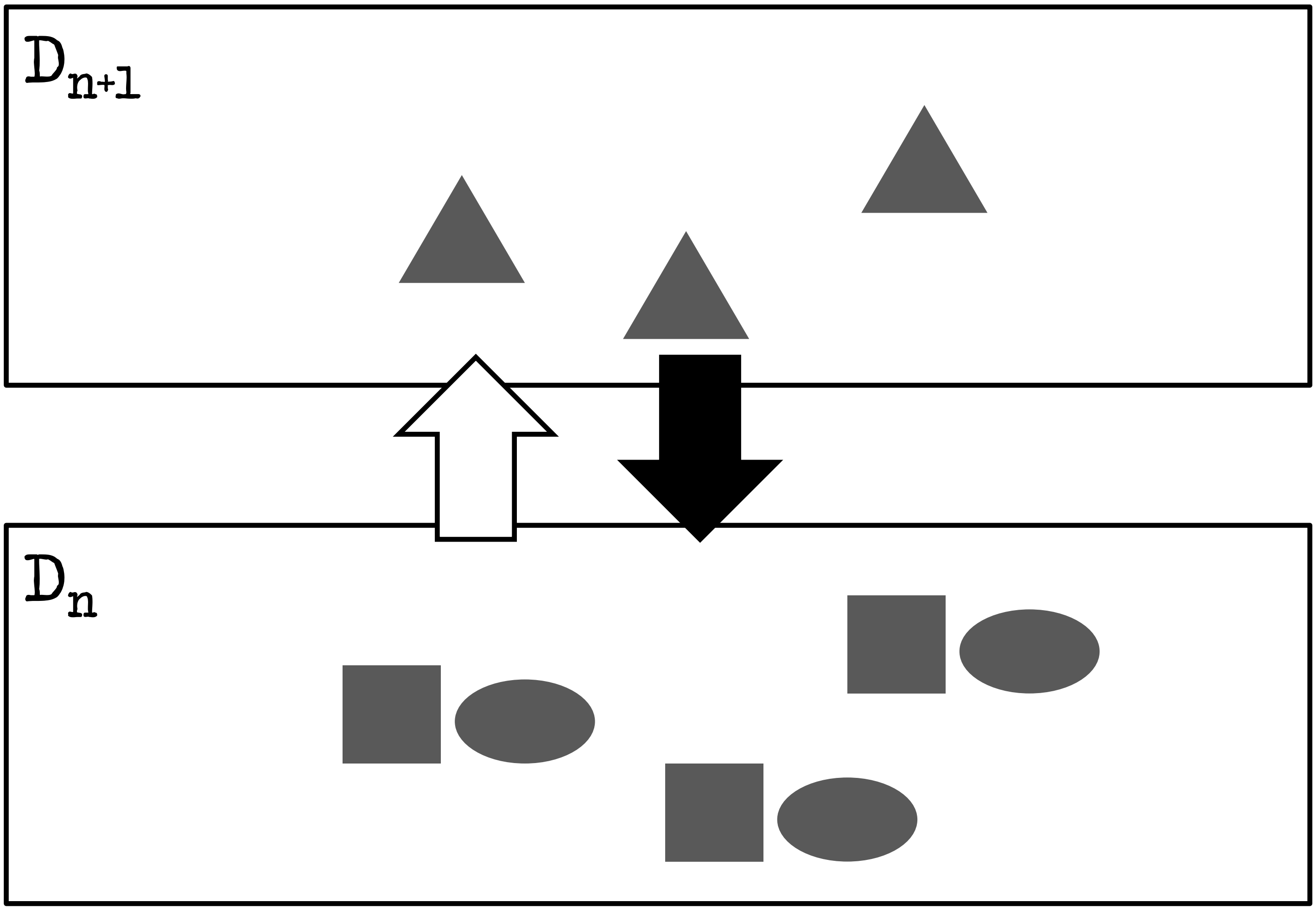
$$where\ OB(p_{L_D}) == OB(q_{L_{D-1}})$$

$$L_D$$

$$\Big\Downarrow \quad \begin{array}{l}\text{Transformation}\\ \text{Interpretation}\end{array}$$

$$L_{D-1}$$

Transformation



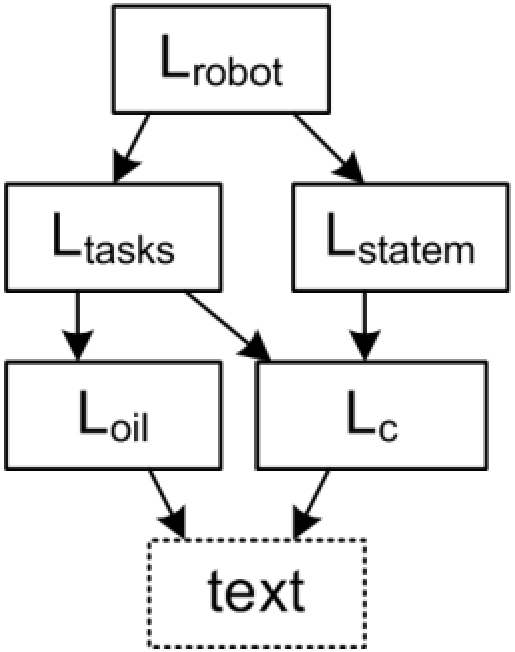
Transformation

```
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

$$L_D \xrightarrow{\text{Transformation}} L_{D-1}$$

Known Semantics!

Transformation

$$L_D$$

Correct!? $\Downarrow$ Transformation

$$L_{D-1}$$

Transformation

$$\begin{tikzcd} \text{Tests (D)} \arrow[d, Rightarrow] & L_D \arrow[d, Rightarrow, "\text{Transformation}"] \\ \text{Tests (D-1)} & L_{D-1} \end{tikzcd}$$

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

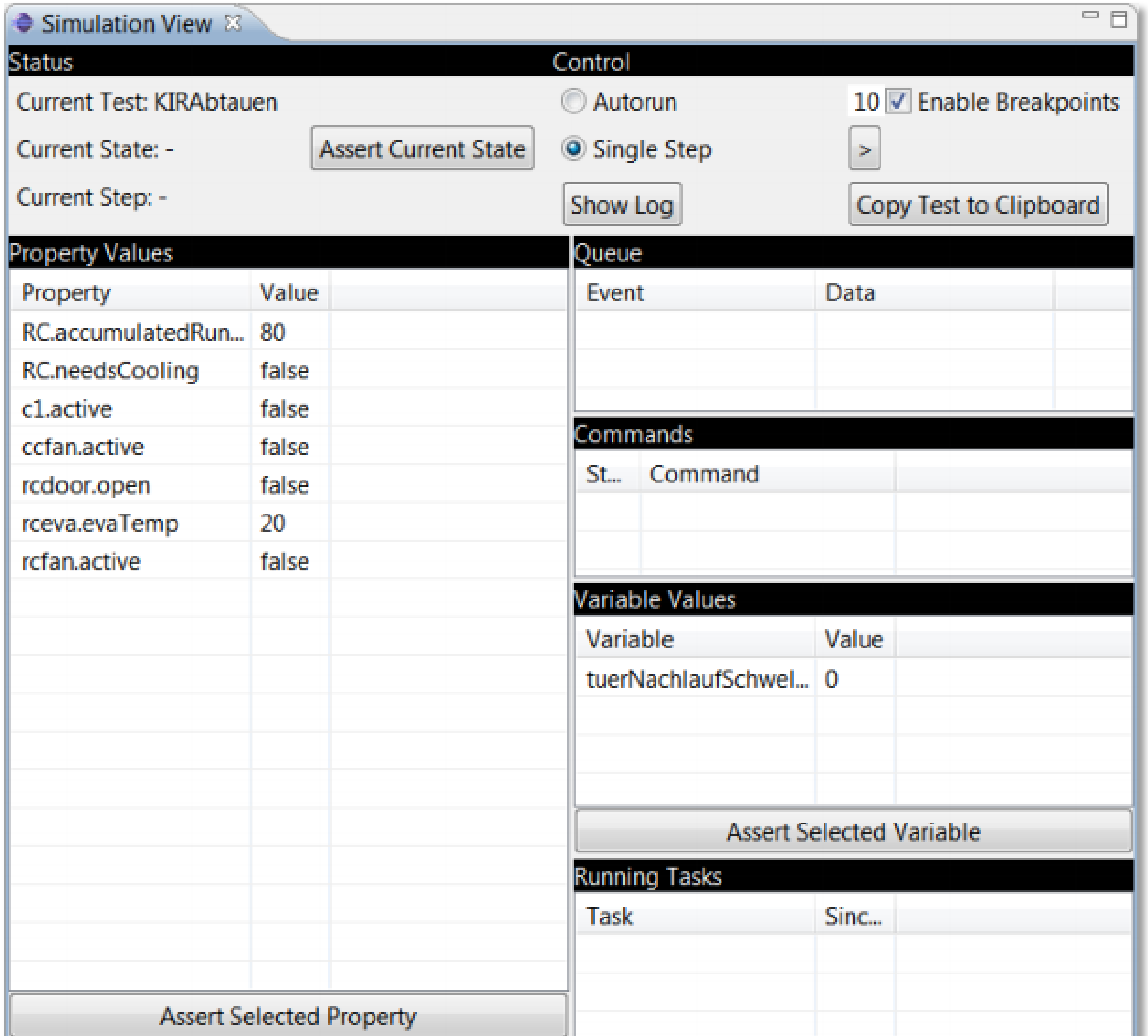
Refrigerators

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
	premiun 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	[illegible]
				1998-12-31	2007-9-24	Jan De Jong	Old Age Pension	Accrued Right in service period	387.7449	[illegible]
				1998-12-31	2007-9-24	Jan De Jong	Old Age Pension	Years of service in service period	10.8082	[illegible]
				1998-12-31	2007-9-24	Jan De Jong	Old Age Pension	Pension base average FP	8250	[illegible]

Example

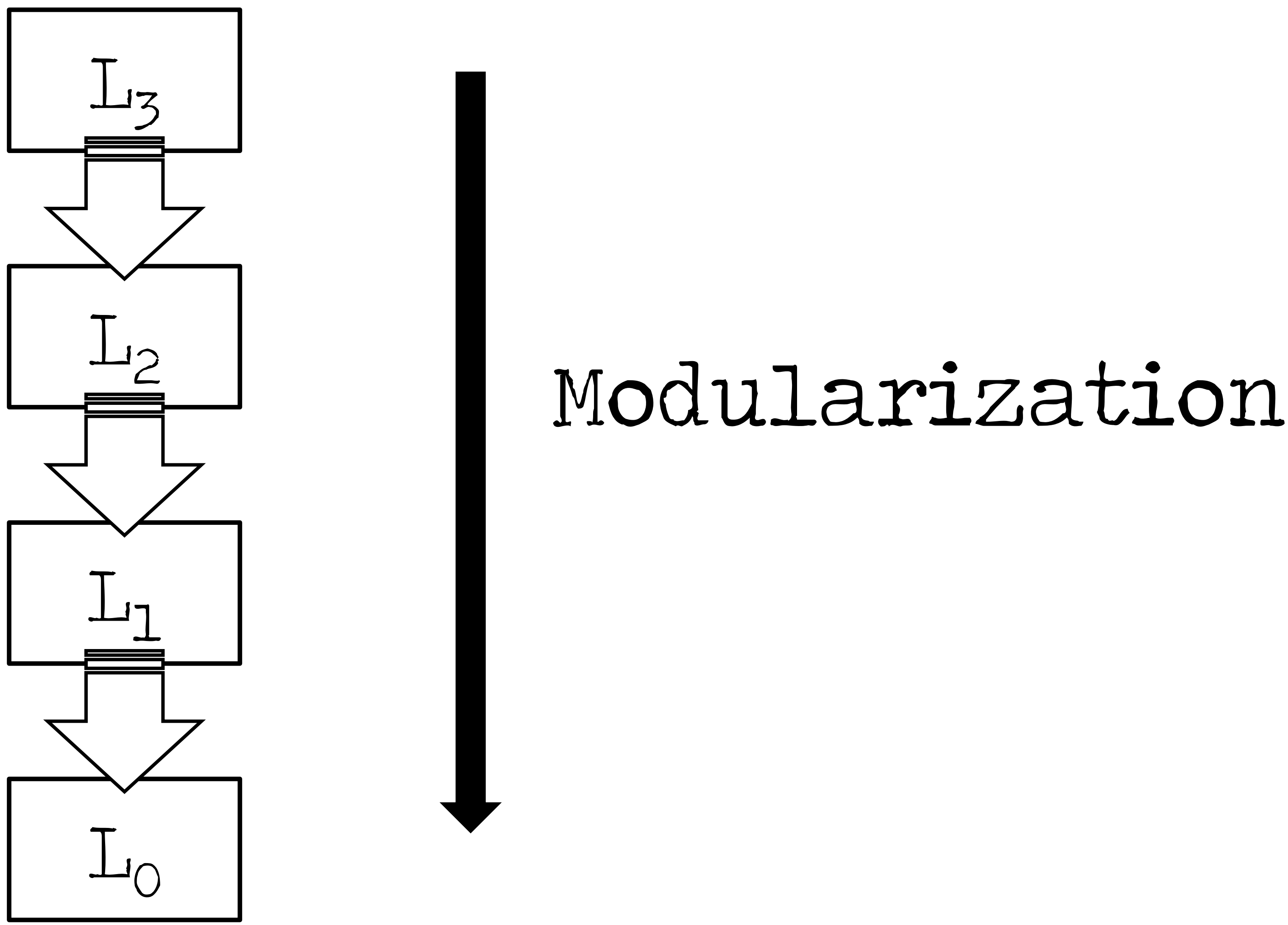
Pension Plans



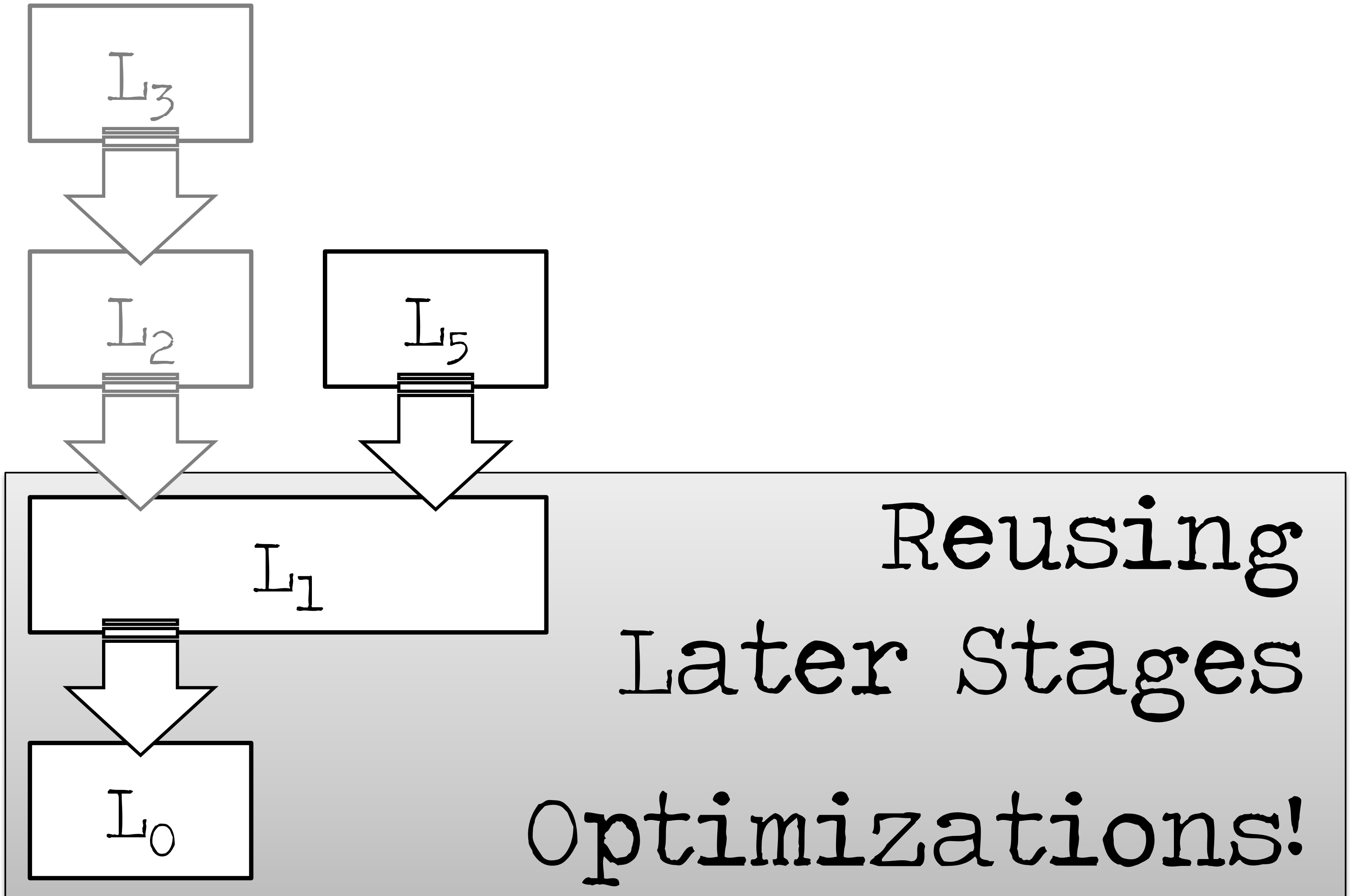
Example

Refrige
rators

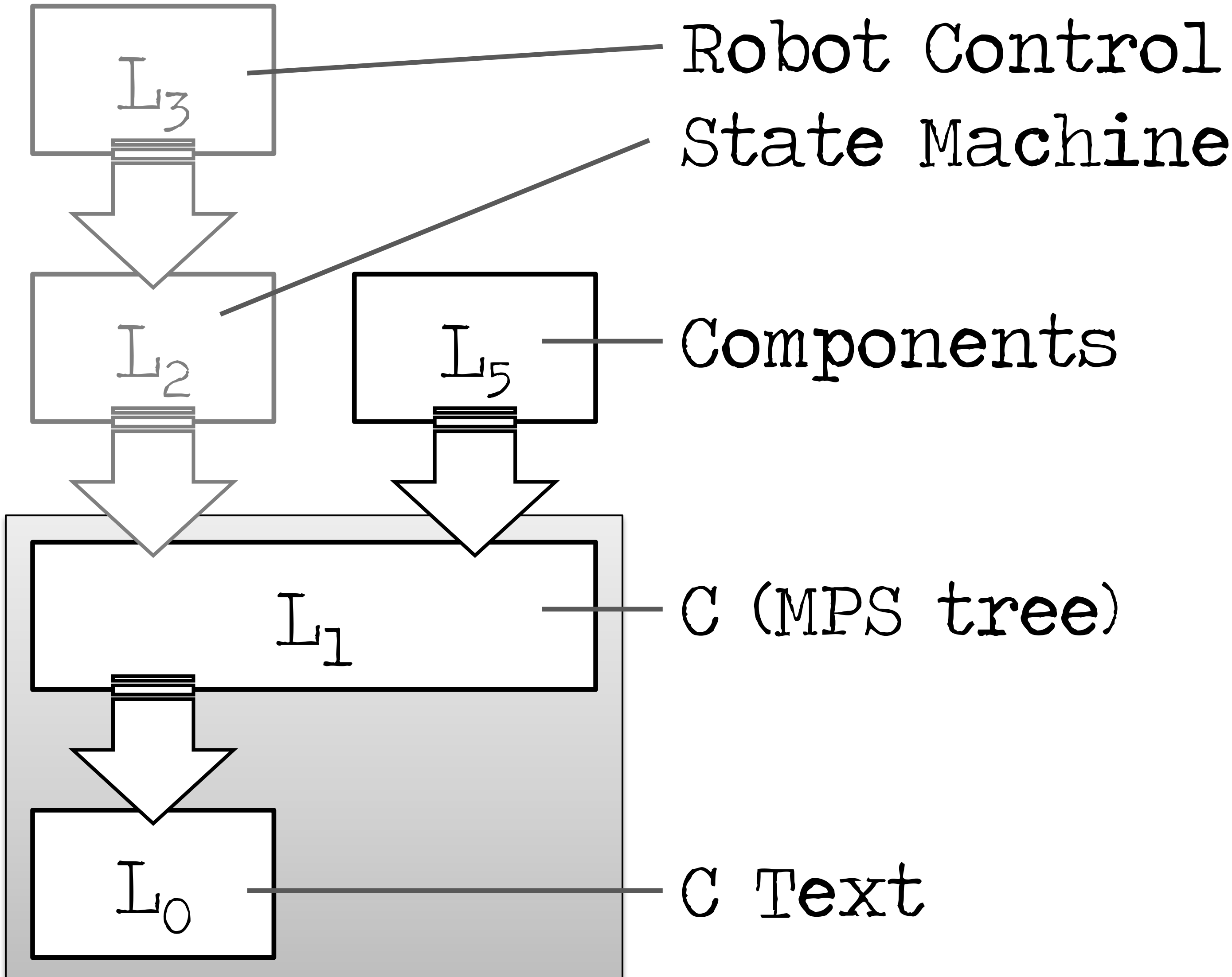
Multi-Stage



Multi-Stage: Reuse



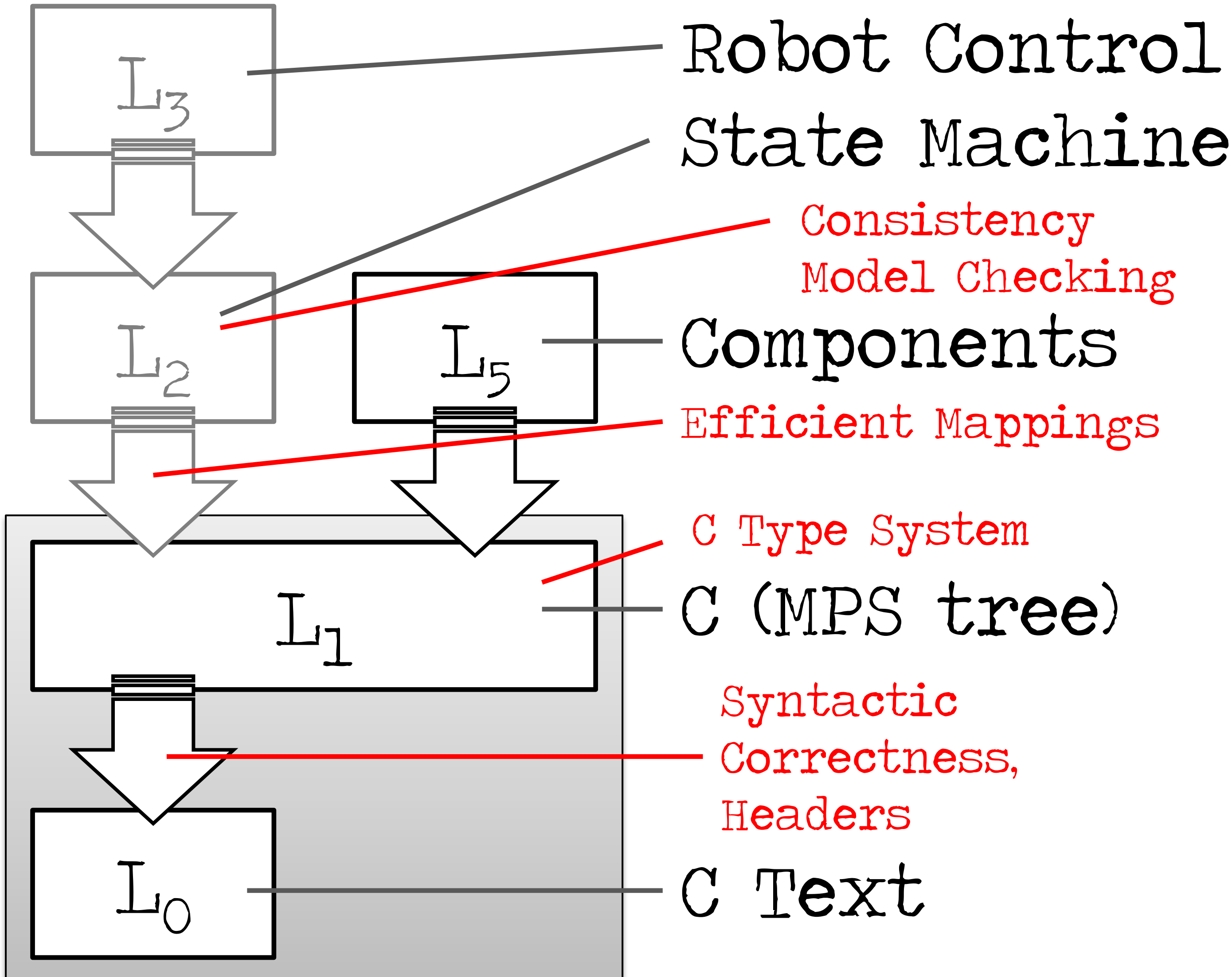
Multi-Stage: Reuse



Example

Exten
ded C

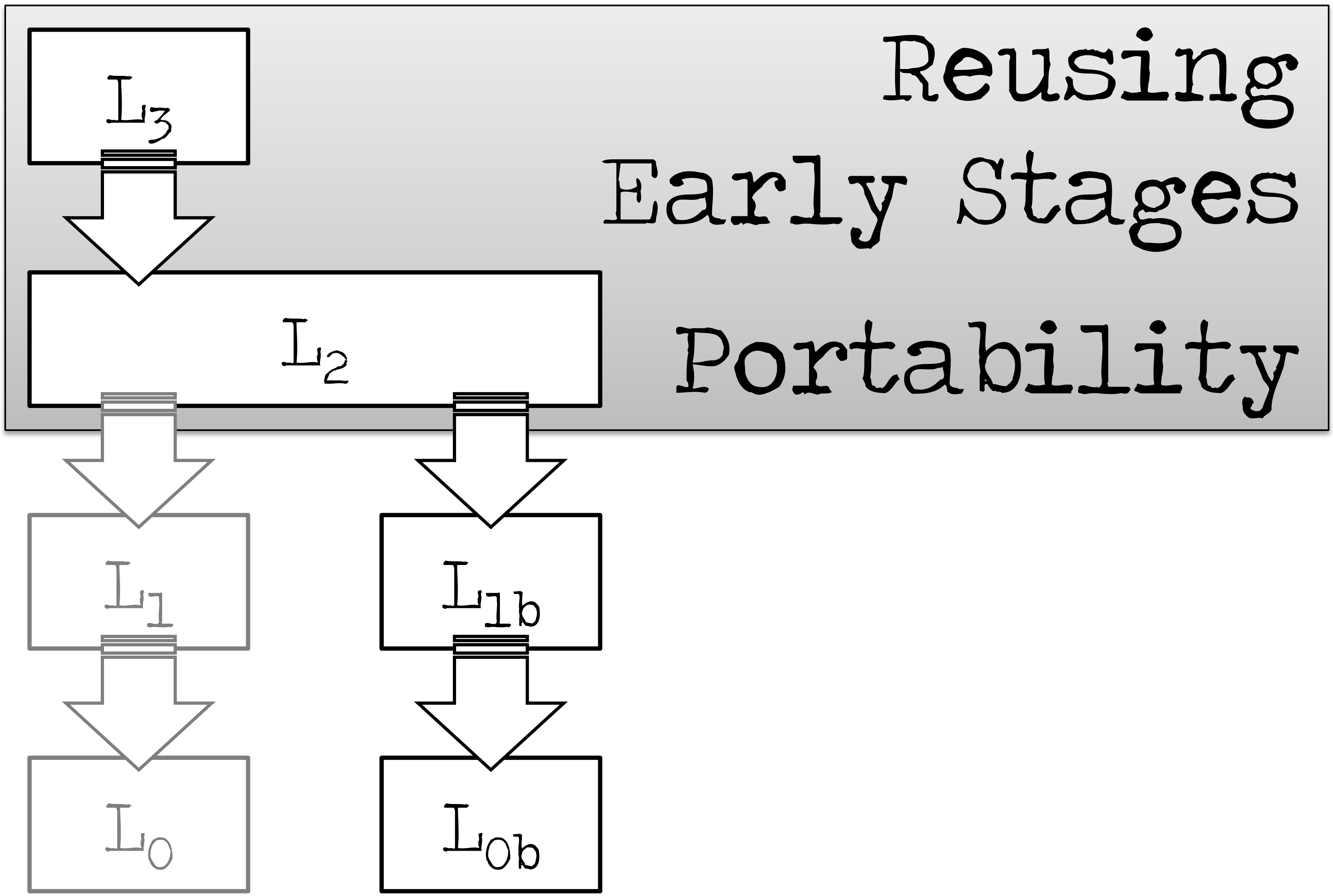
Multi-Stage: Reuse



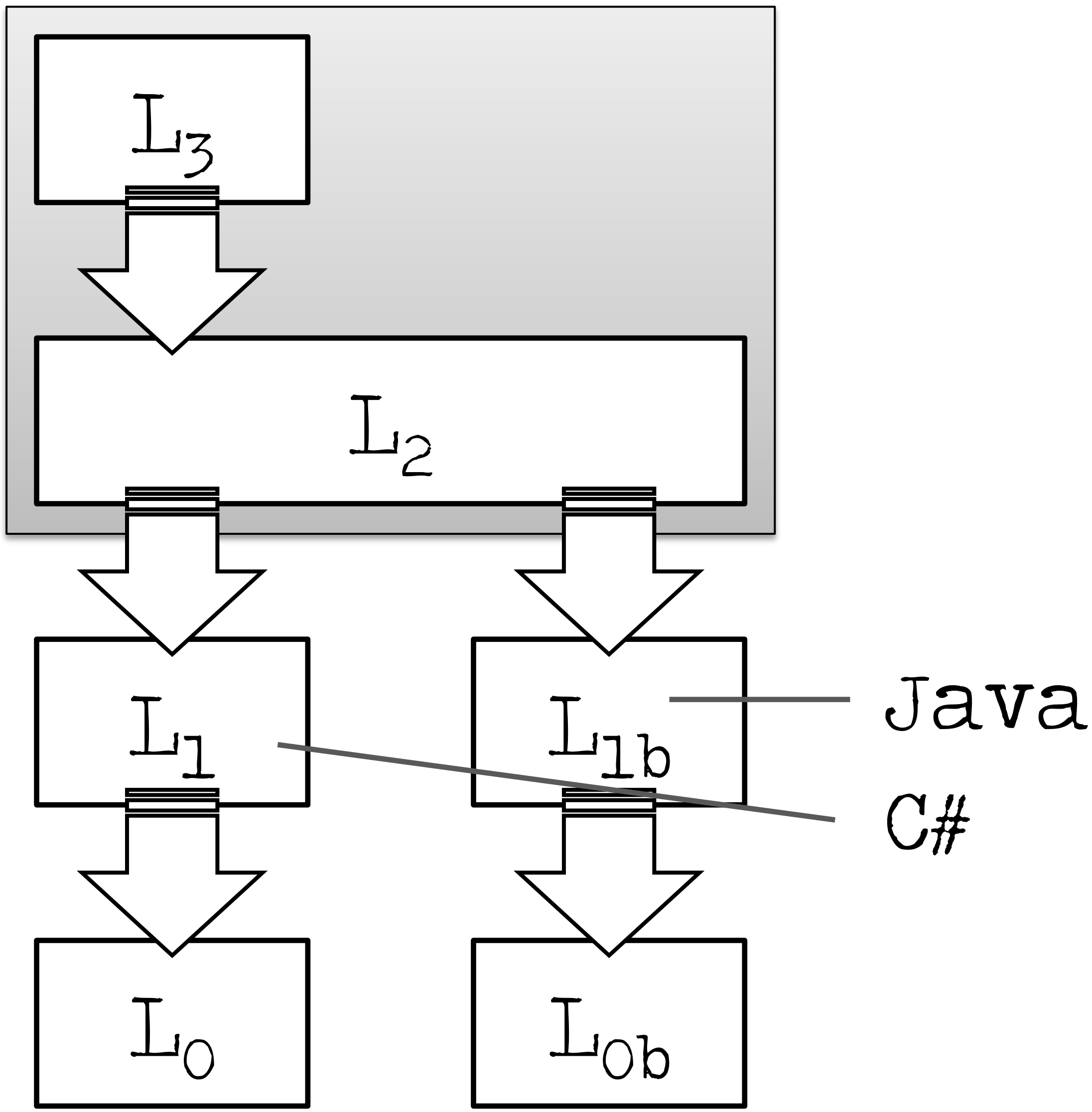
Example

Extended C

Multi-Stage: Reuse



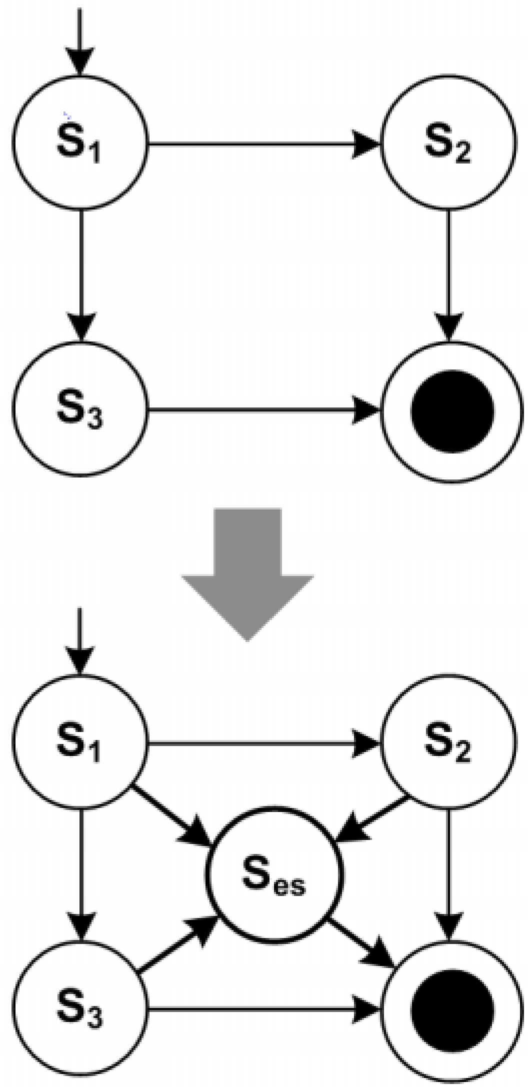
Multi-Stage: Reuse



Example

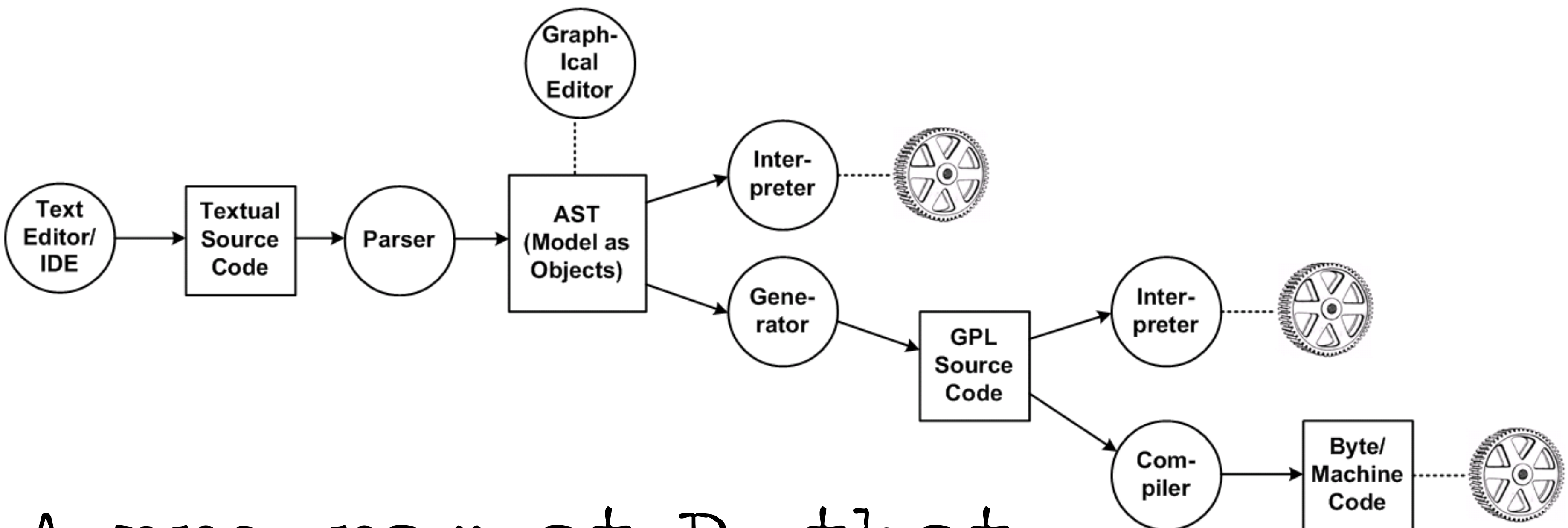
Exten
ded C

Multi-Stage: Preprocess



Adding an optional, modular emergency stop feature

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
	Accrued Right last final pay			2004-1-1	2007-9-24	Jan De Jong	Old Age Pension	Accrued right	705.0589	705.0589
	premiun 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

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
}

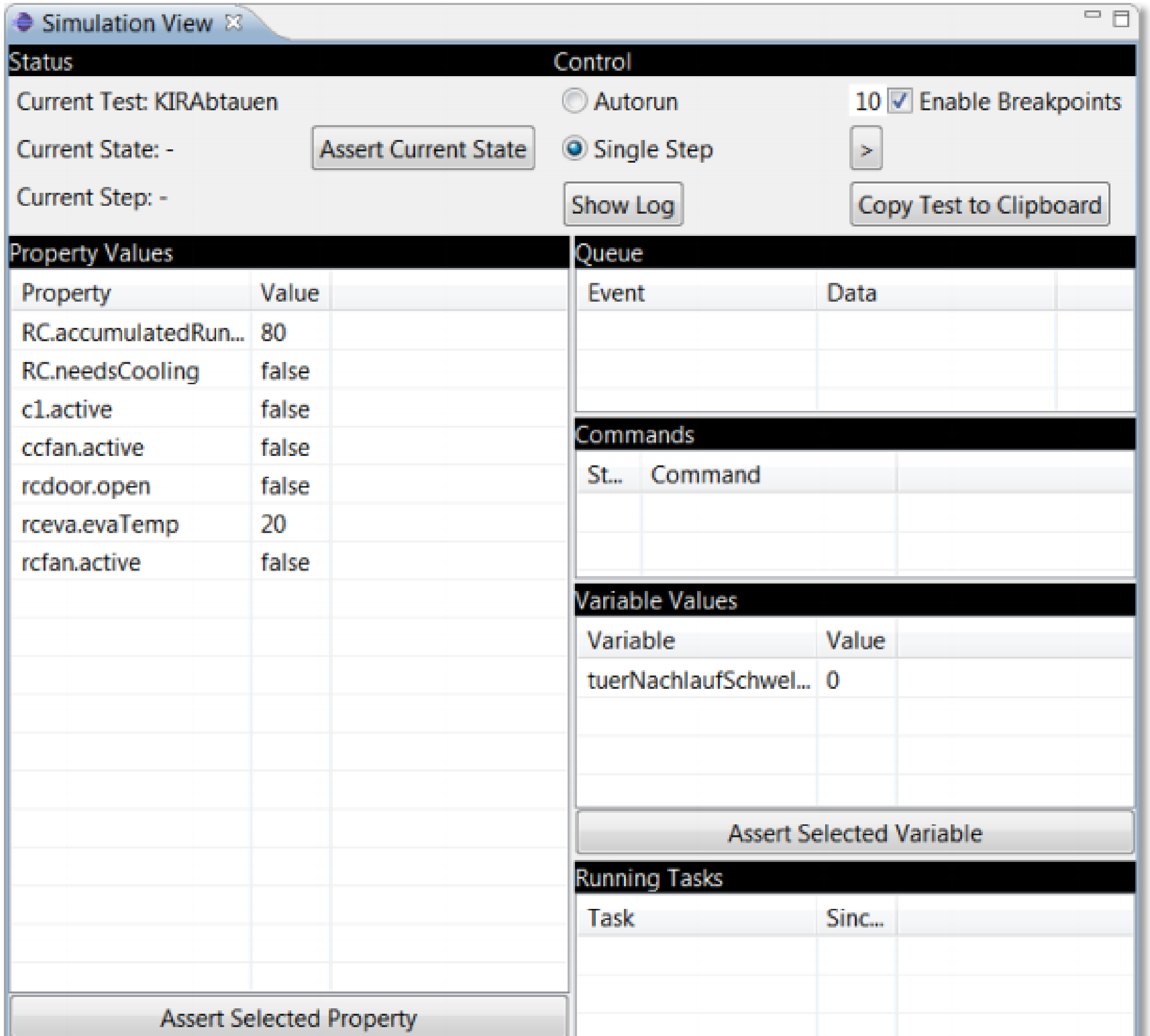
step 10
assert-currentstate-is noCooling

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

Refrigerators



Example

Refrige
rators

Transformation	Interpretation

Transformation	Interpretation
+ Code Inspection	

Transformation	Interpretation
+ Code Inspection OSGi Generators	

Example

Compo
nents

Transformation

+ Code Inspection
+ Debugging

Interpretation

Transformation

+ Code Inspection
+ Debugging
  Platform Inter-
  actions

Interpretation

Example

Refrige
rators

Transformation

+ Code Inspection
+ Debugging
+ Performance & Optimization

Interpretation

Transformation	Interpretation

- Code Inspection
- Debugging
- Performance & Optimization

  Efficiency for Real-Time S/w

  Memory Use

Example

Extended C

Transformation

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

Interpretation

Transformation

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

Web Frameworks and Standards

Interpretation

Example

Web DSL

Transformation

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

Interpretation

+ Turnaround Time

Transformation

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

Interpretation

+ Turnaround Time
  Testing

Example

Pension Plans

Example

Refrigerators

Transformation

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

Interpretation

+ Turnaround Time
+ Runtime Change

Transformation

+ Code Inspection
+ Debugging
+ Performance & Optimization
+ Platform Con-formance

Interpretation

+ Turnaround Time
+ Runtime Change
  Change Business Rules without Redeployment

Example

Pension Plans

Def: Semantics

… via mapping to lower level

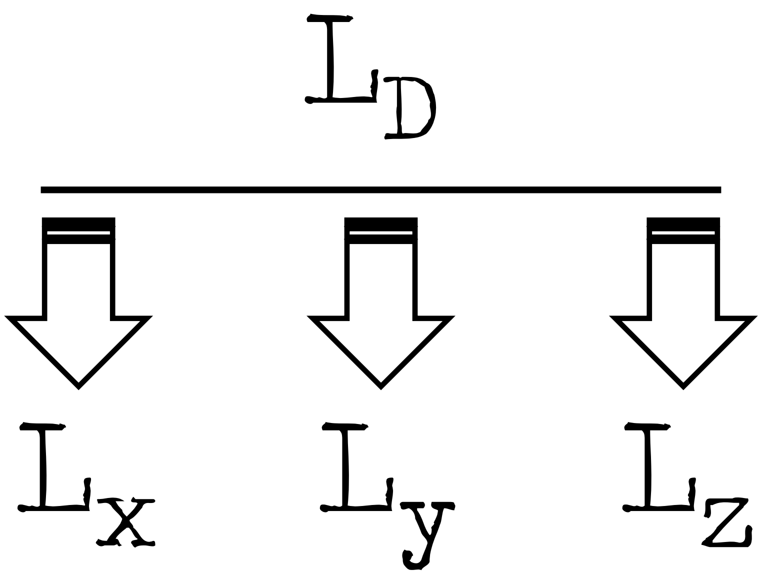
L_D

$\Downarrow$ Transformation
Interpretation

L_{D-1}

Multiple Mappings

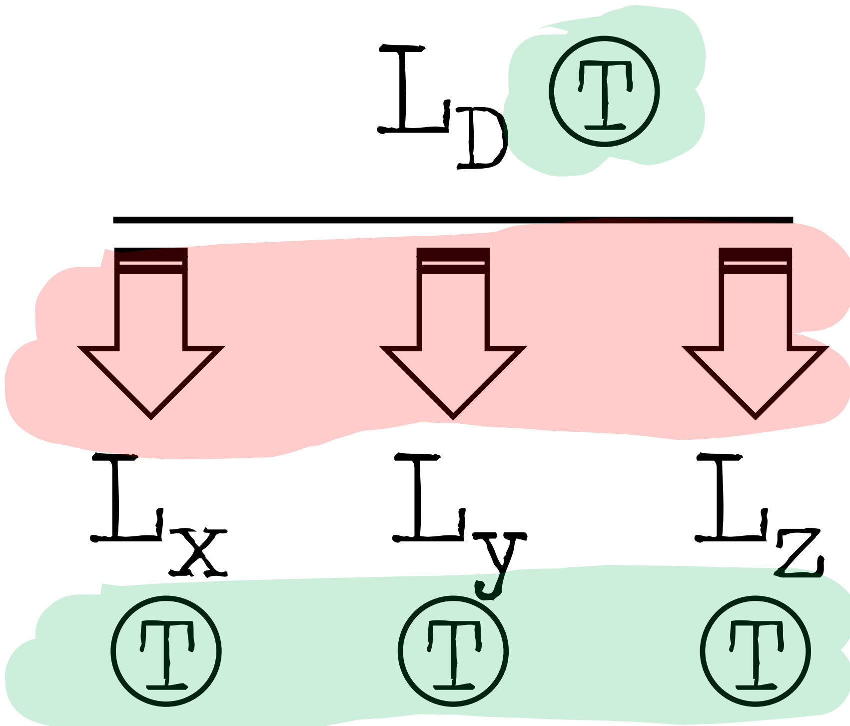
… at the same time



Similar Semantics?

Multiple Mappings

… at the same time



Similar Semantics?

all green!

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Example

Pension Plans

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        }
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    }
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        set RC.rclight->active = false
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    }
    exit {
        perform rcfanabschalttask after max( 5, tuerNachlaufSchwelle-currStep ) {
            set RC.rcfan->active = false
        }
    }
```

```
prolog {
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step 5
assert-currentstate-is abtauen
assert-value cc.c1->active is false
step 15
assert-currentstate-is noCooling
```

Example

Refrigerators

Reduced Expressiveness

bad?	maybe.
good?	maybe!

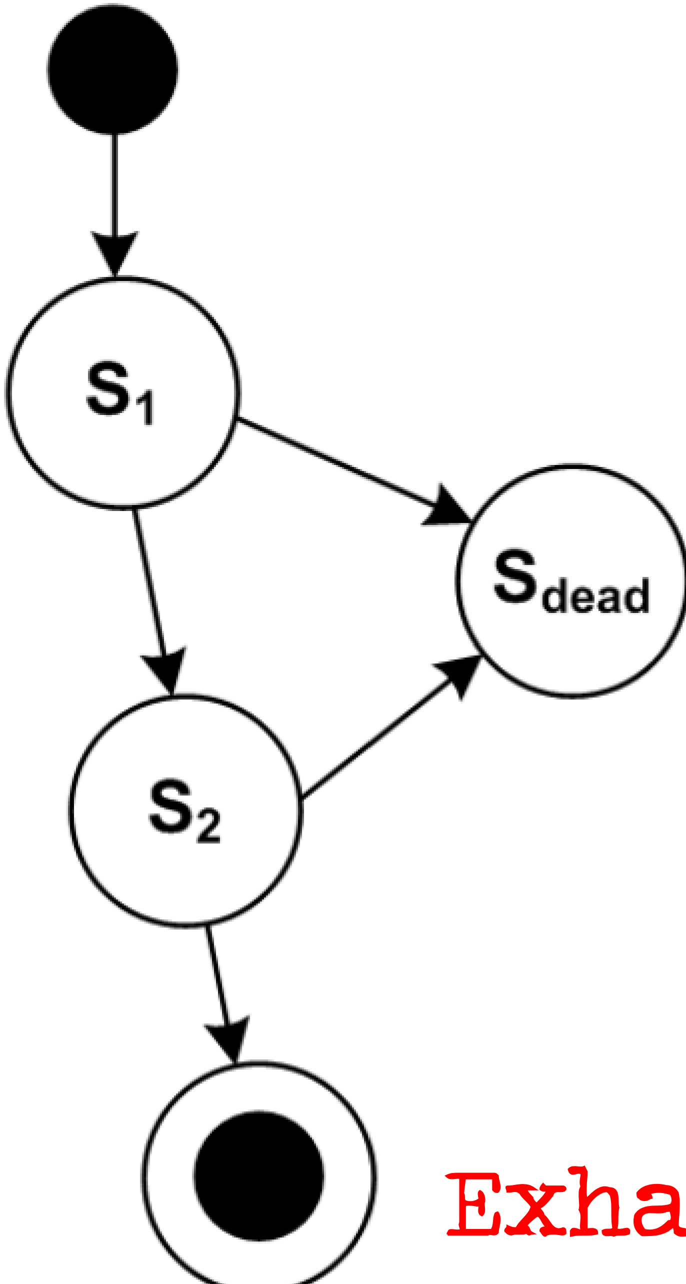
Reduced Expressiveness

bad?	maybe.
good?	maybe!

Model Checking

SAT Solving

Exhaustive Search, Proof!



Unique State Names

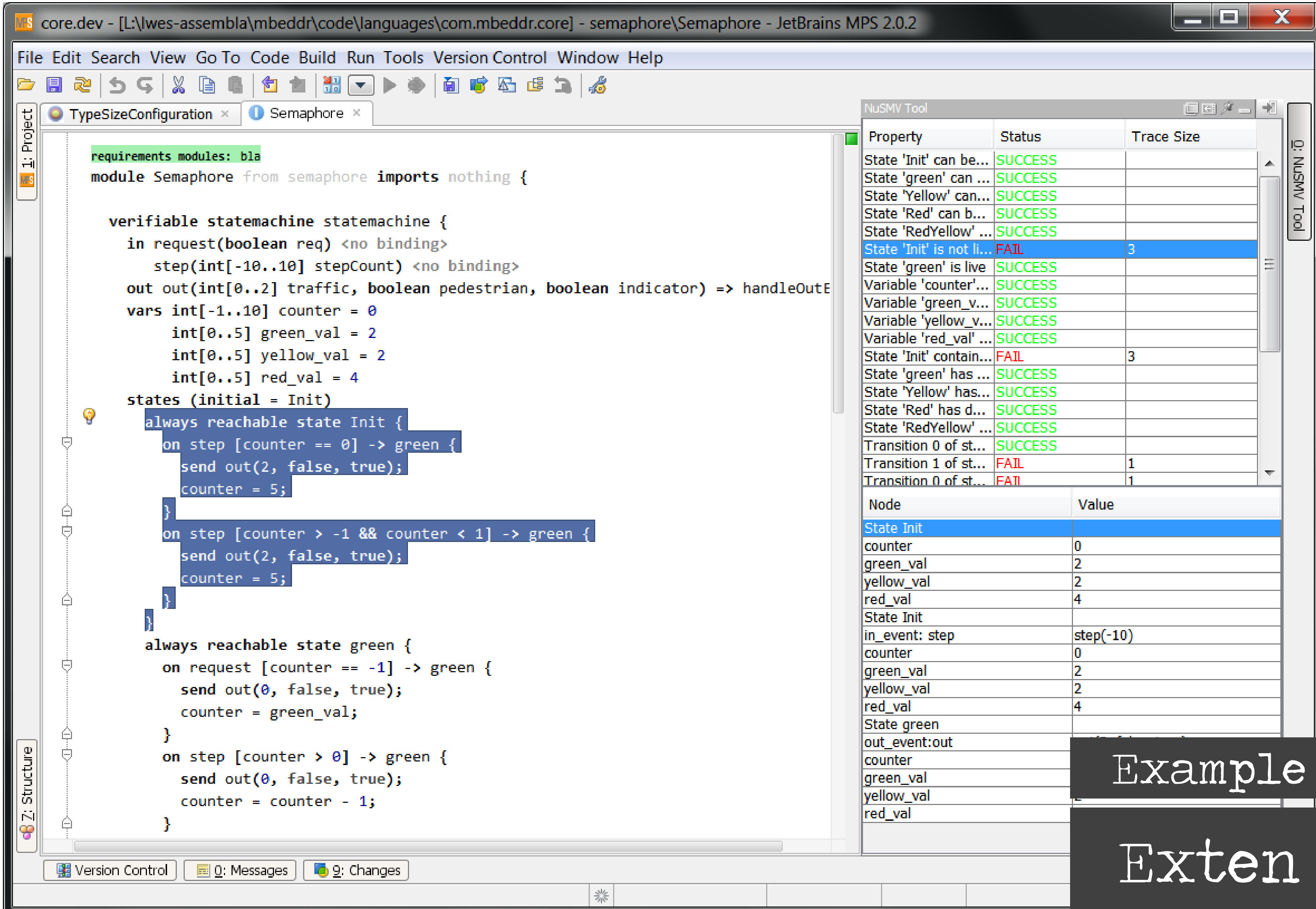
Unreachable States

Dead End States

Guard Decidability

Reachability

Exhaustive Search, Proof!



Example

Extended 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

Extended C

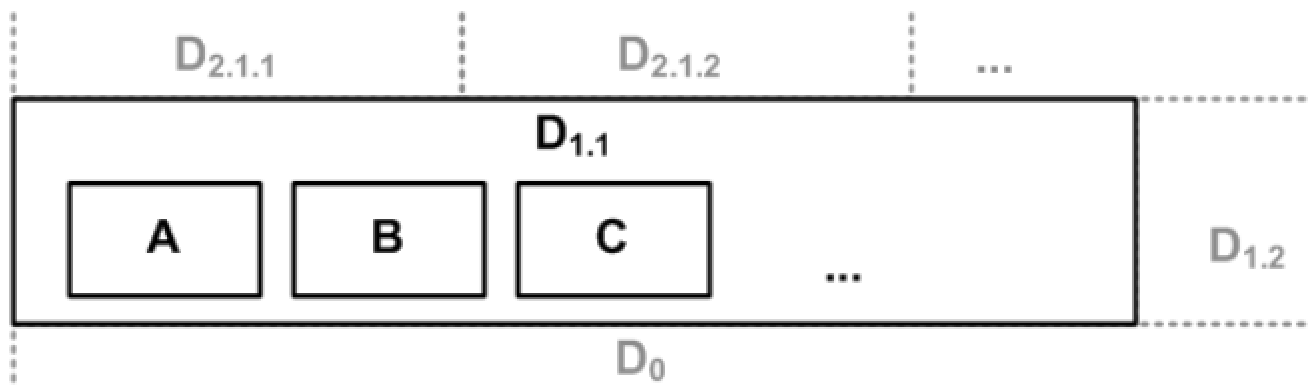
Separation of Concerns

expressivity	completeness
coverage	paradigms
semantics	modularity
separation of concerns	concrete syntax

process

Several Concerns

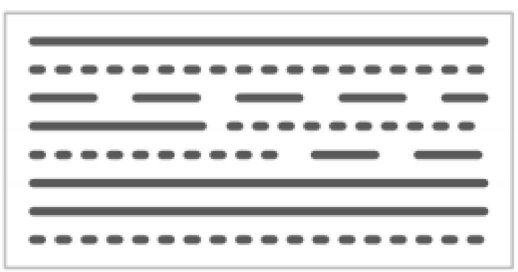
… in one domain



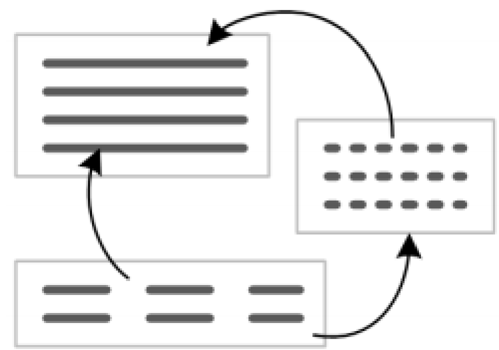
Several Concerns

… in one domain

integrated into
one fragment



separated into
several fragments

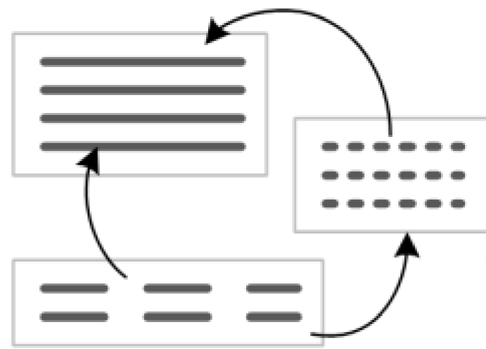


Viewpoints

$$\forall r \in Refs_f \mid fo(r.to) = fo(r.from) = f$$

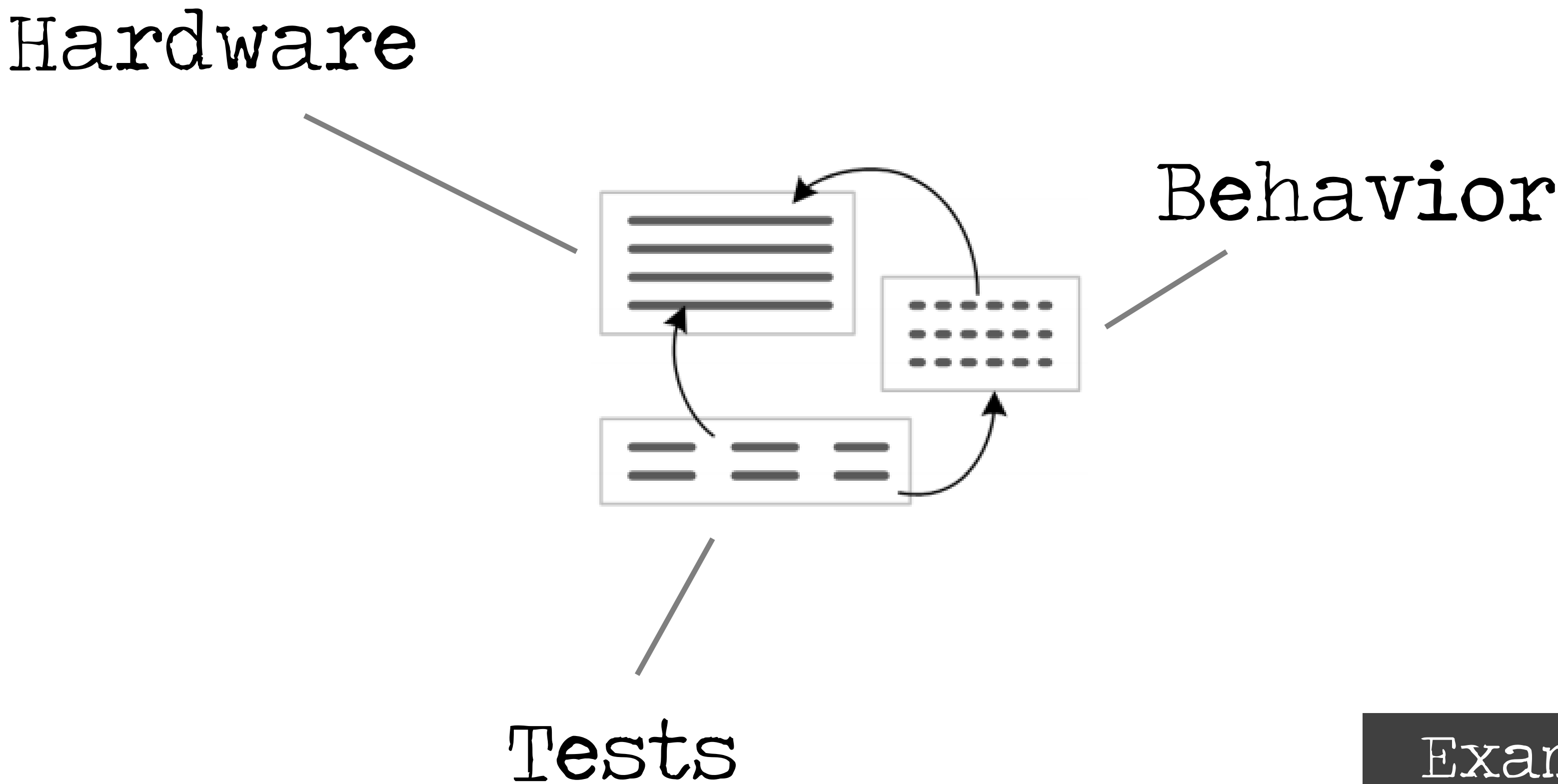
$$\forall e \in E_f \mid lo(co(e)) = l$$

independent



dependent

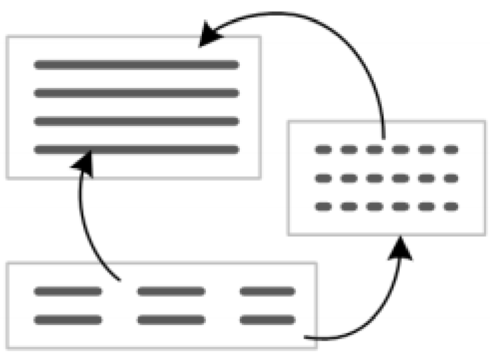
Viewpoints



Example

Refrige
rators

Viewpoints: Why?



Sufficiency

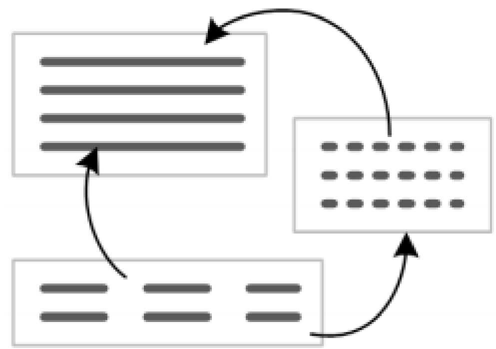
Different Stakeholders

Different Steps in Process - VCS unit!

Viewpoints

Hardware

Product
Management



Behaviour

Thermo-
dynamics-
Experts

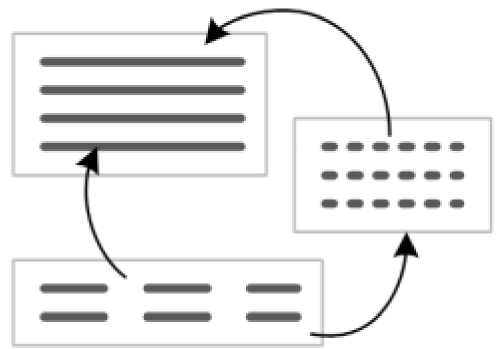
Tests

Example

Refrige
rators

Viewpoints

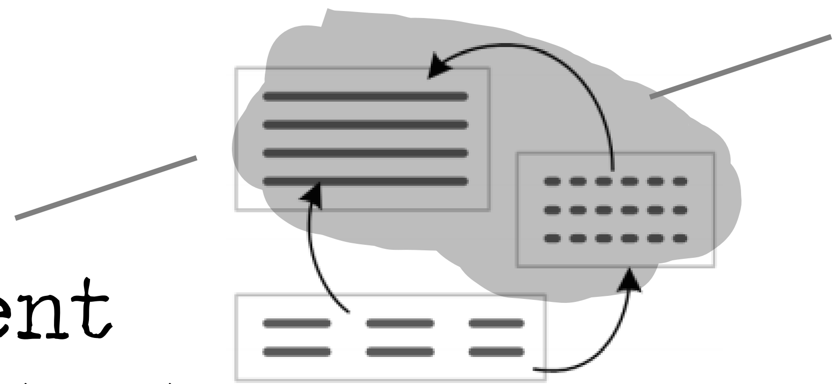
independent



sufficient?

contains all the data for running a meaningful transformation

Viewpoints



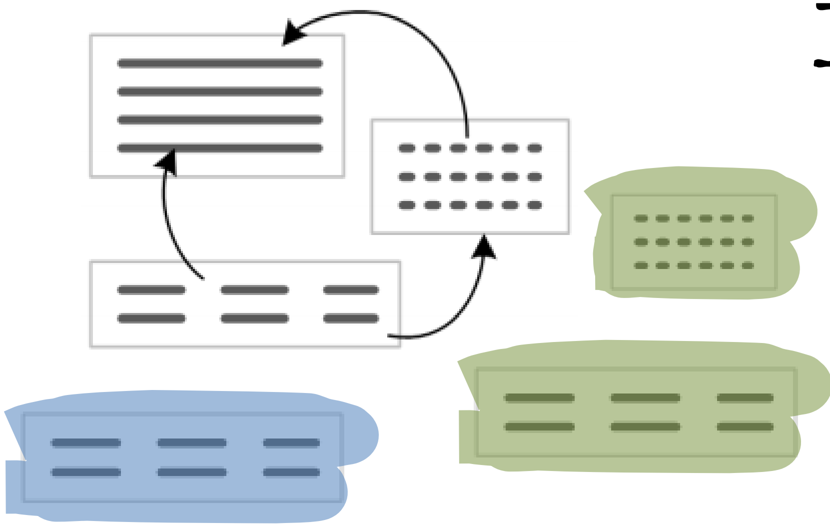
sufficient
implementation code

sufficient
Hardware structure documentation

Example

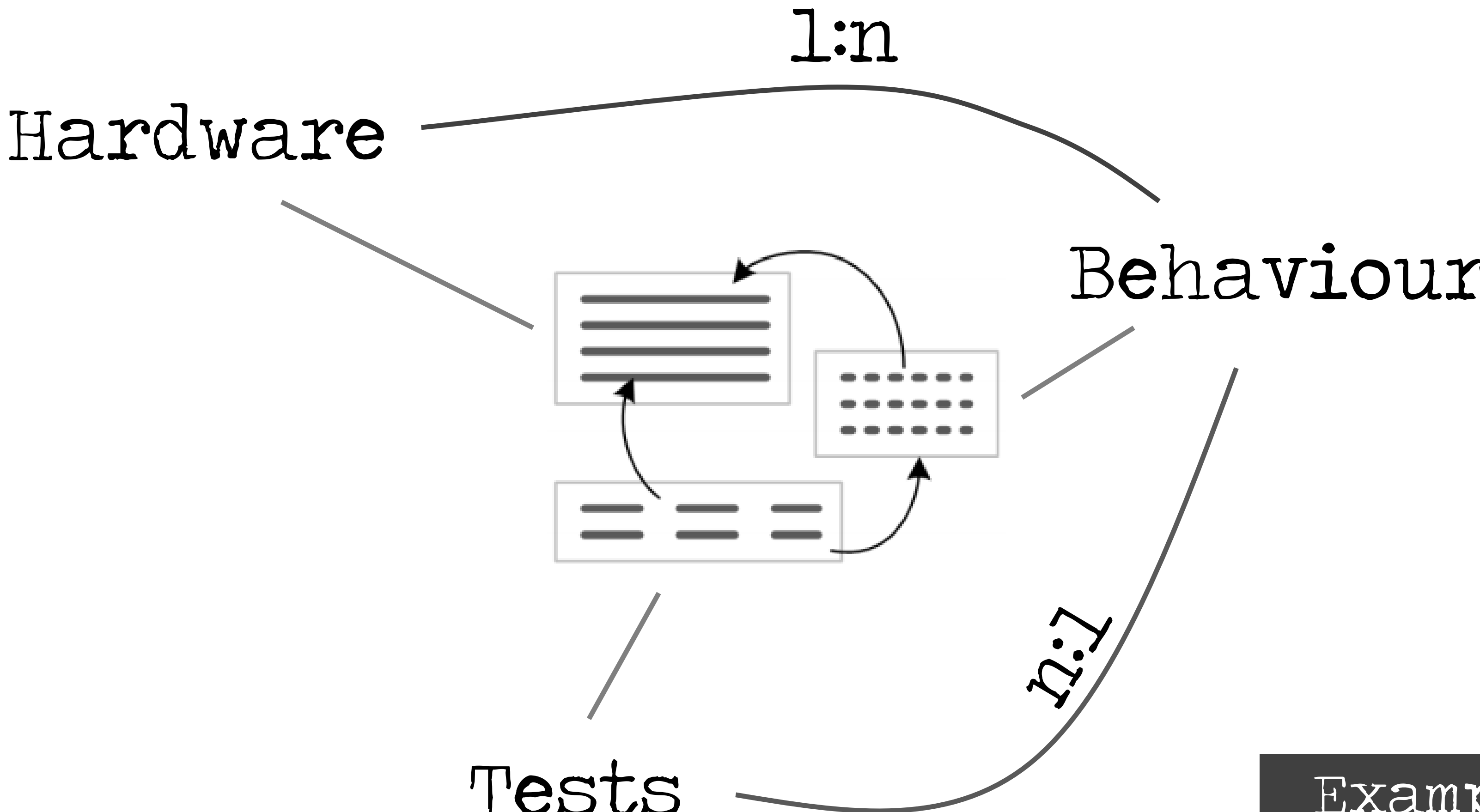
Refrigerators

Viewpoints: Why?



1:n Relationships

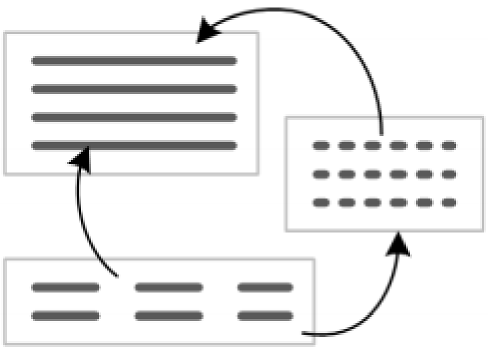
Viewpoints



Example

Refrige
rators

Viewpoints



Well-defined Dependencies

No Cycles!

Avoid Synchronization!
(unless you use a projectional editor)

Language Modularity

expressivity
coverage
semantics
separation of concerns

completeness
paradigms
modularity
concrete syntax

process

Language Modularity, Composition and Reuse (LMR&C)

increase efficiency
of DSL development

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**

Dependencies:

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

Dependencies:

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

Fragment Structure:

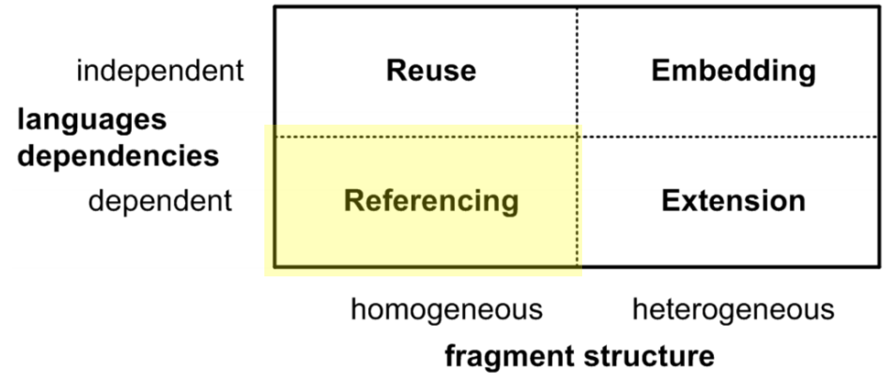
homogeneous vs. heterogeneous („mixing languages")

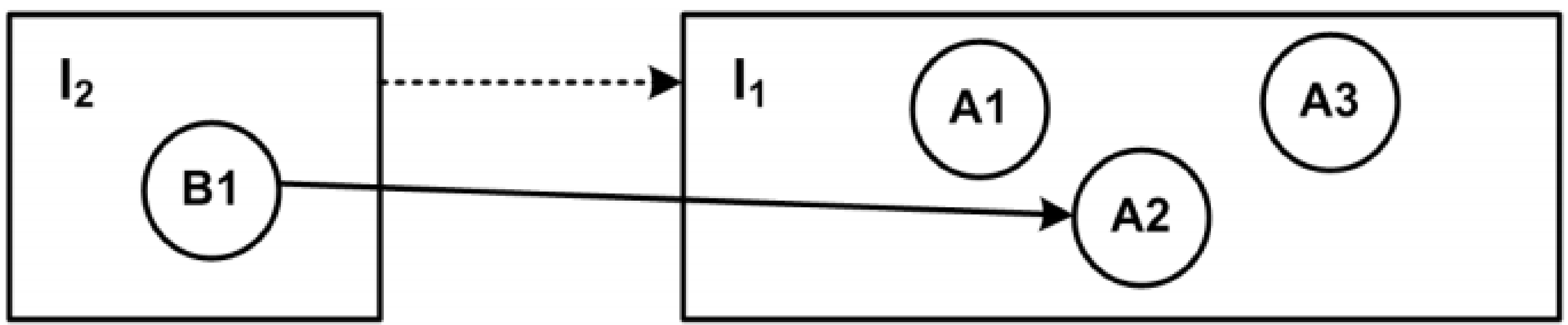
Dependencies & Fragment Structure:

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

fragment structure

Referencing

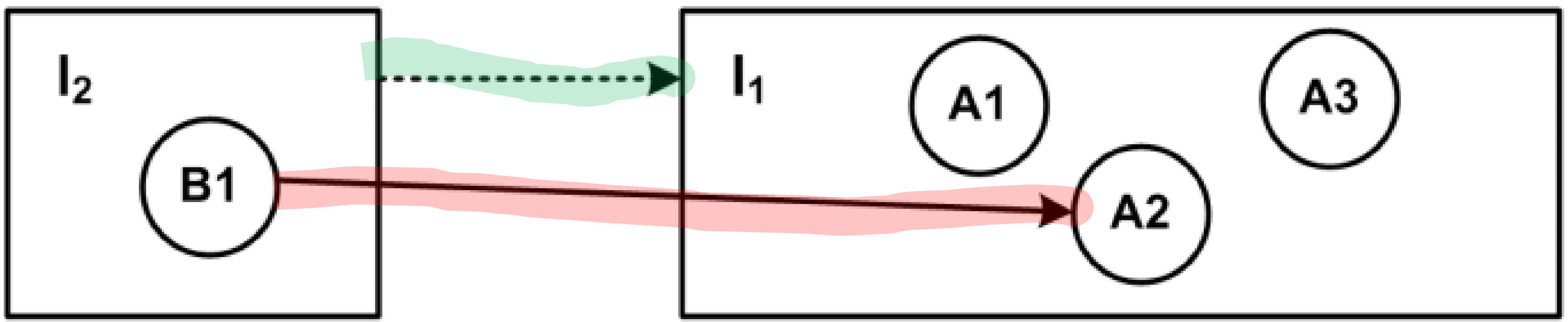




Referencing

languages dependencies \ **fragment structure**	homogeneous	heterogeneous
independent	**Reuse**	**Embedding**
dependent	**Referencing**	**Extension**

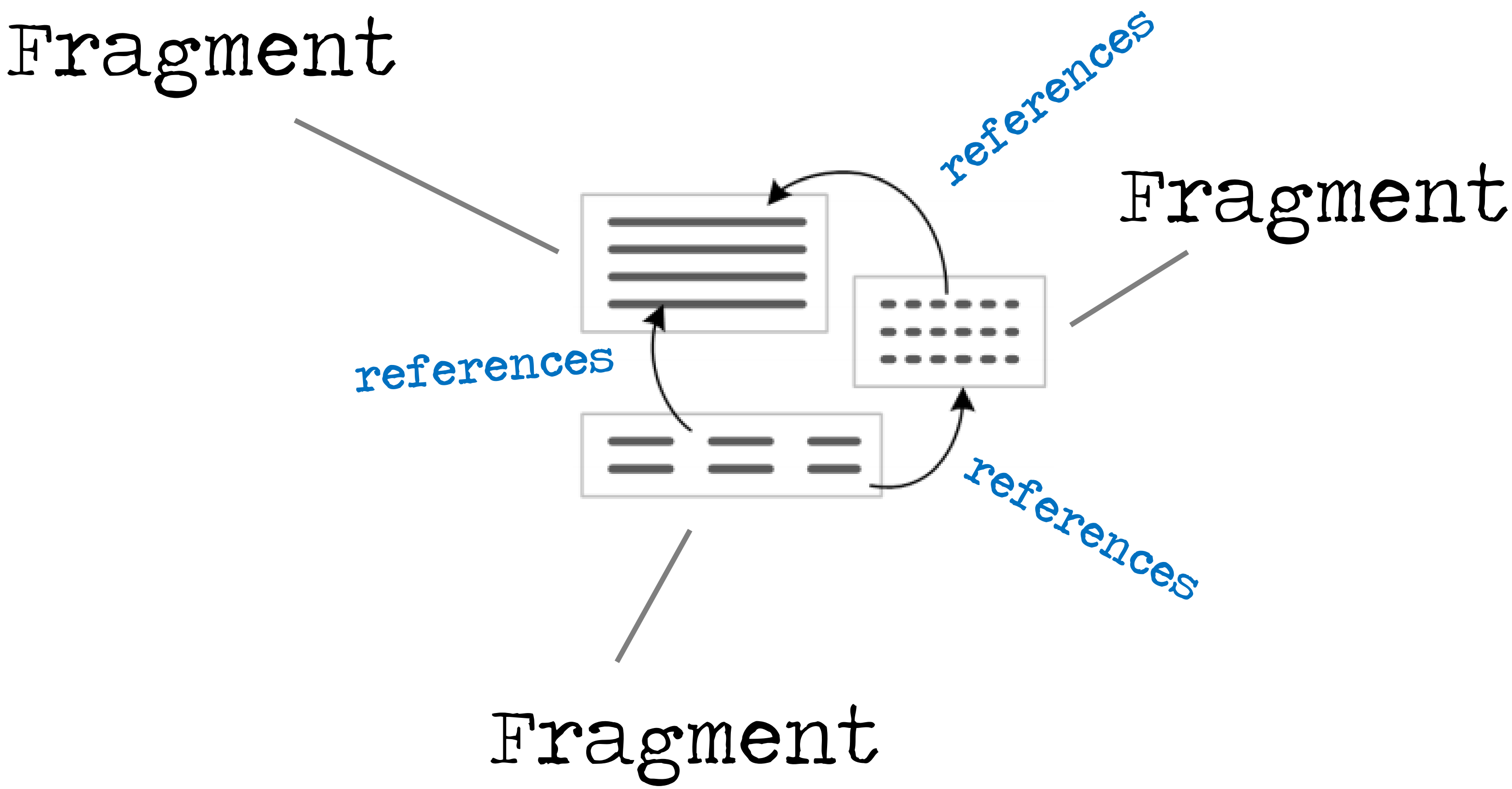
Dependent



No containment

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 {
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        }
    }


state rccooling:
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    }
    exit {
        perform rcfanabschalttask after max( 5, tuerNachlaufSchwelle-currStep ) {
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```

```
prolog {
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assert-value cc.c1->active is false
step 15
assert-currentstate-is noCooling
```

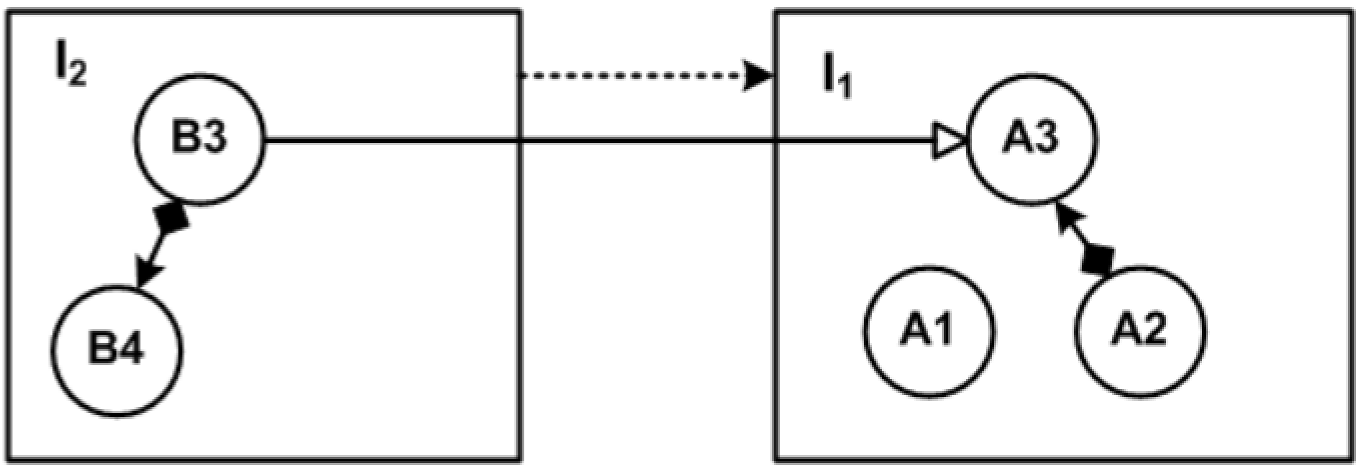
Example

Refrige
rators

Extension

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

fragment structure

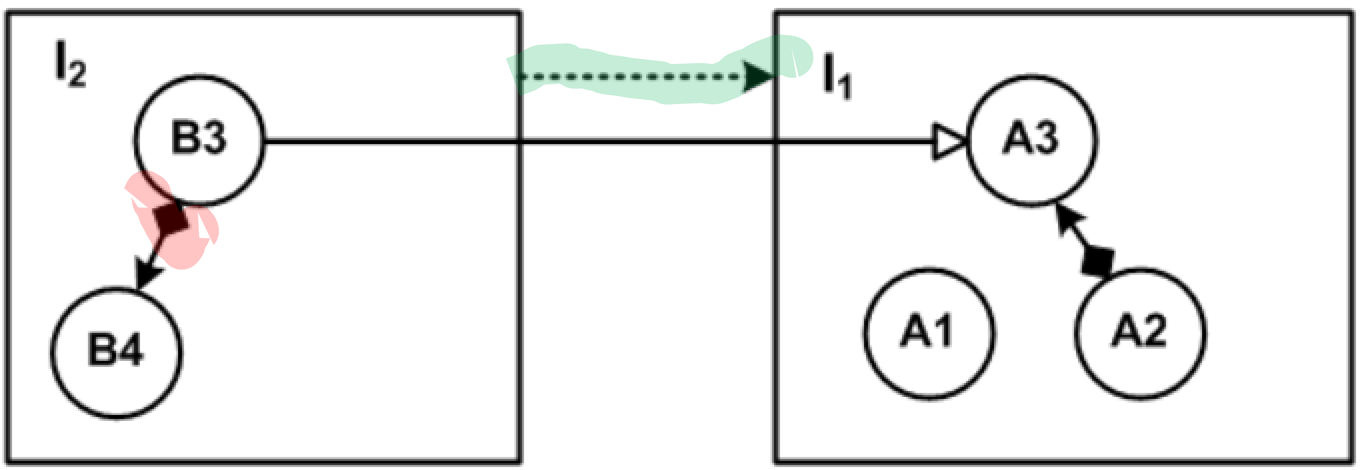


Extension

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

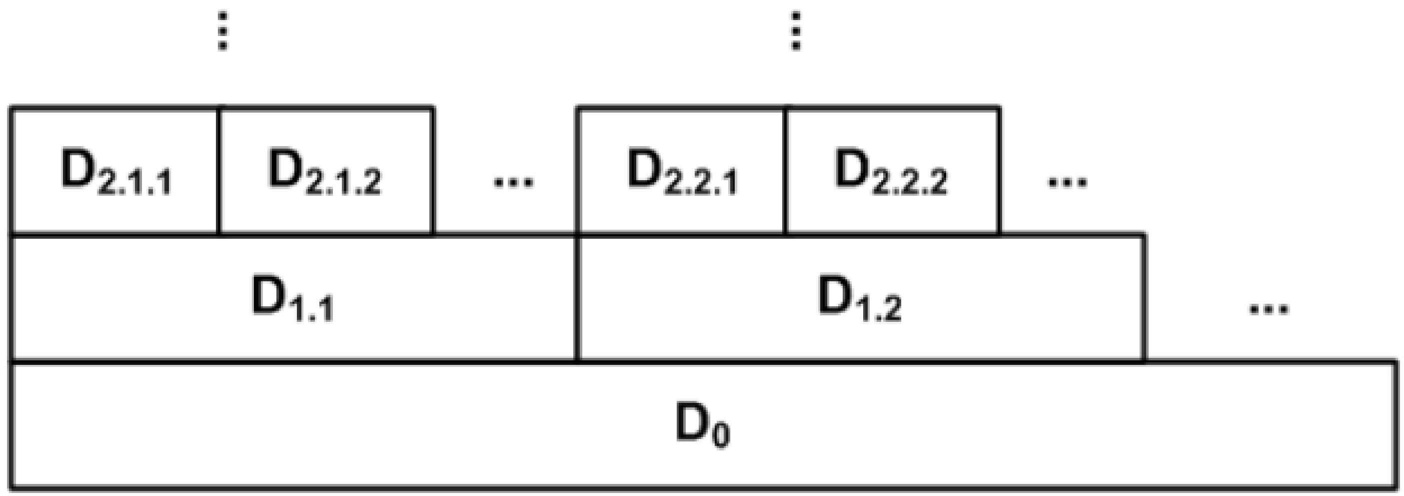
fragment structure

Dependent



Containment

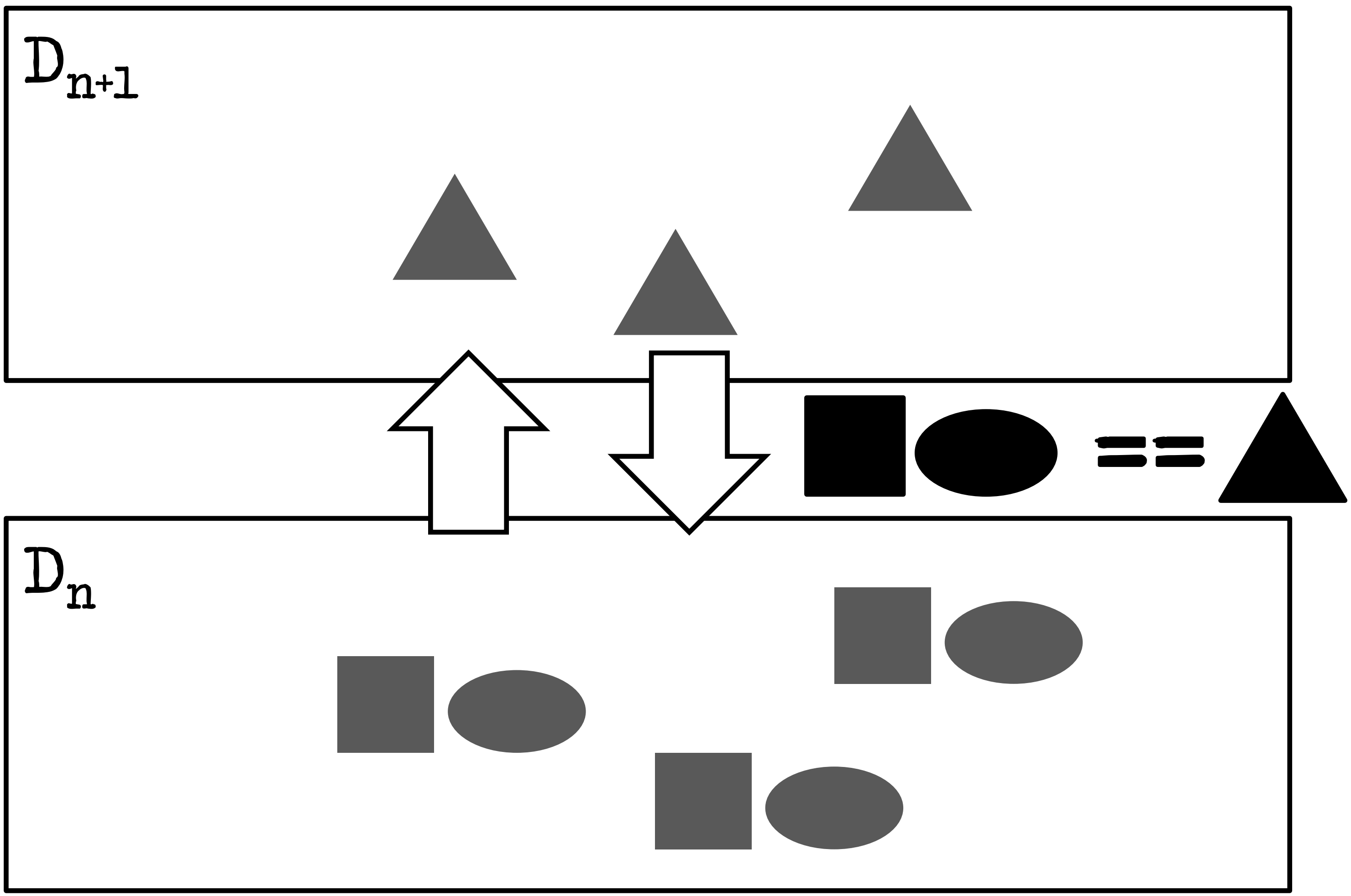
Extension



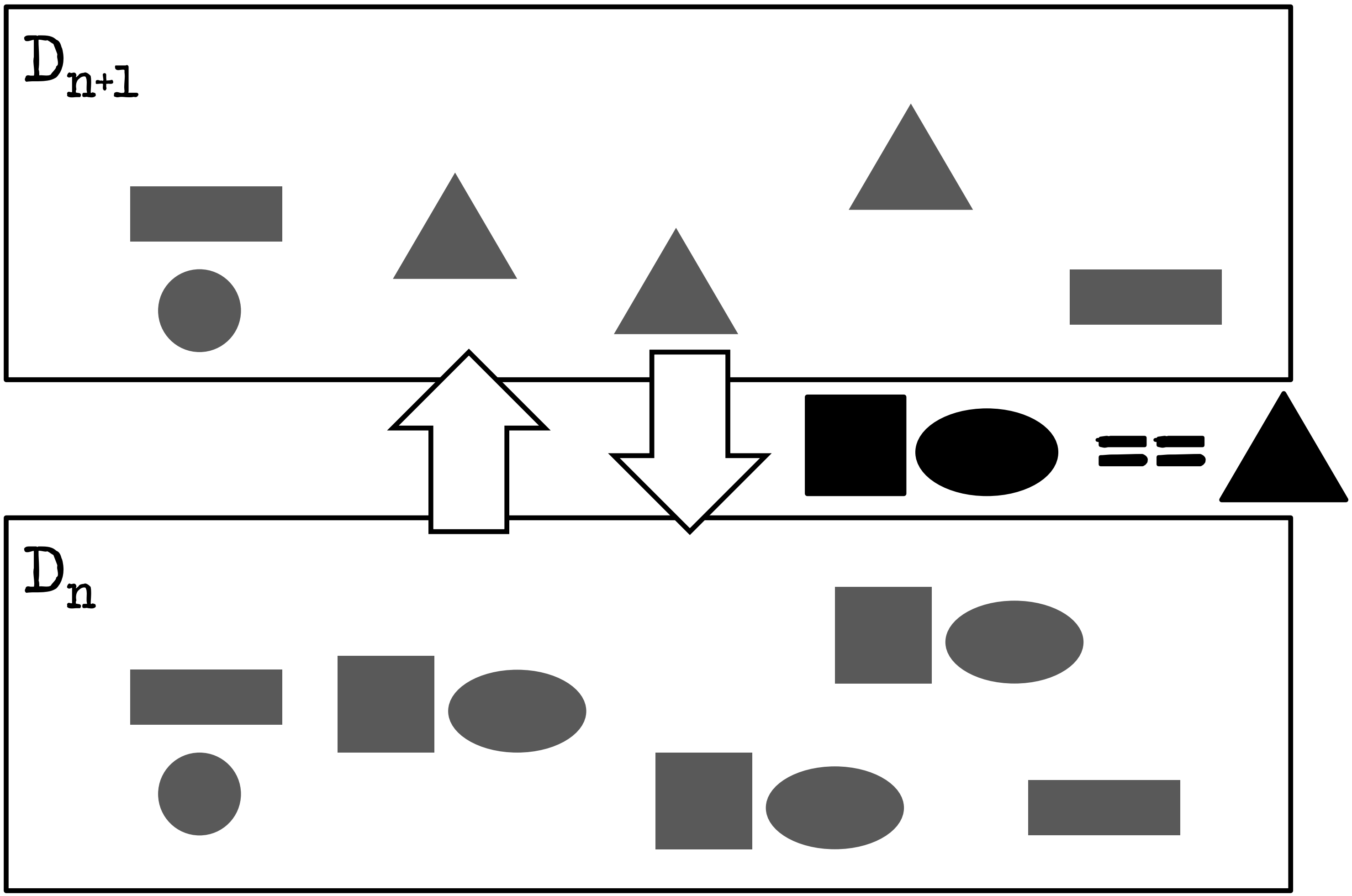
more specialized domains

more specialized languages

Extension

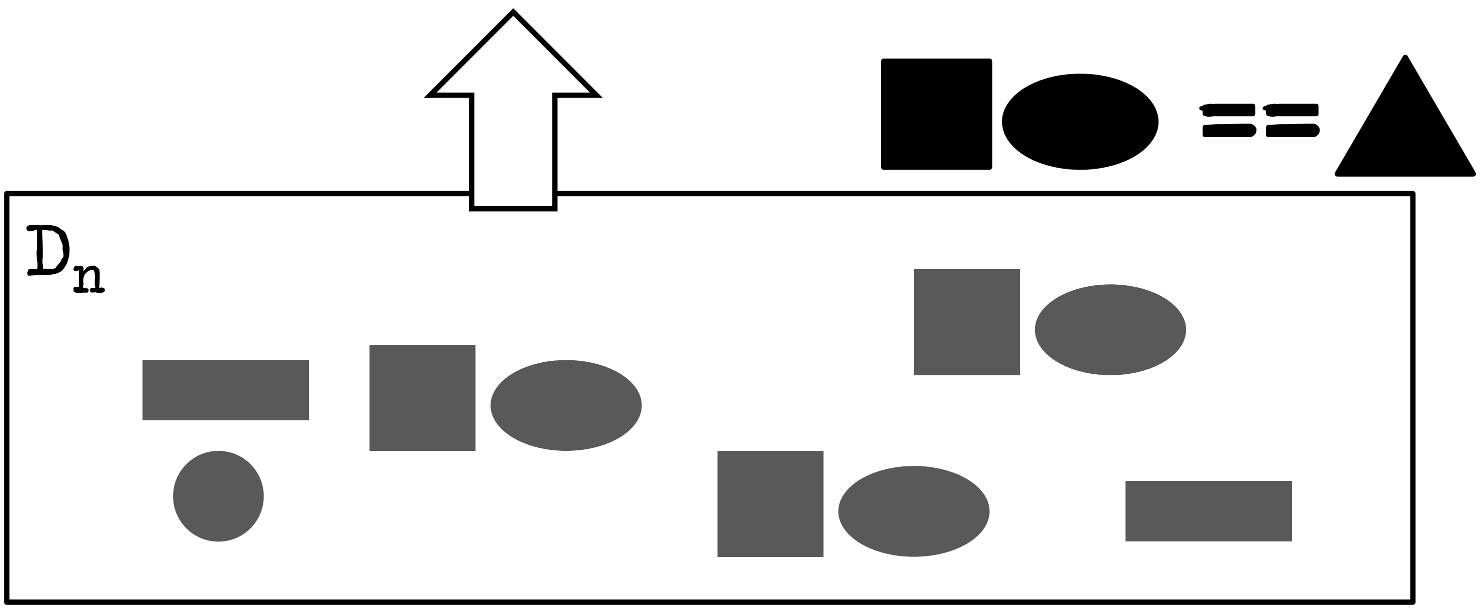


Extension



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);
```

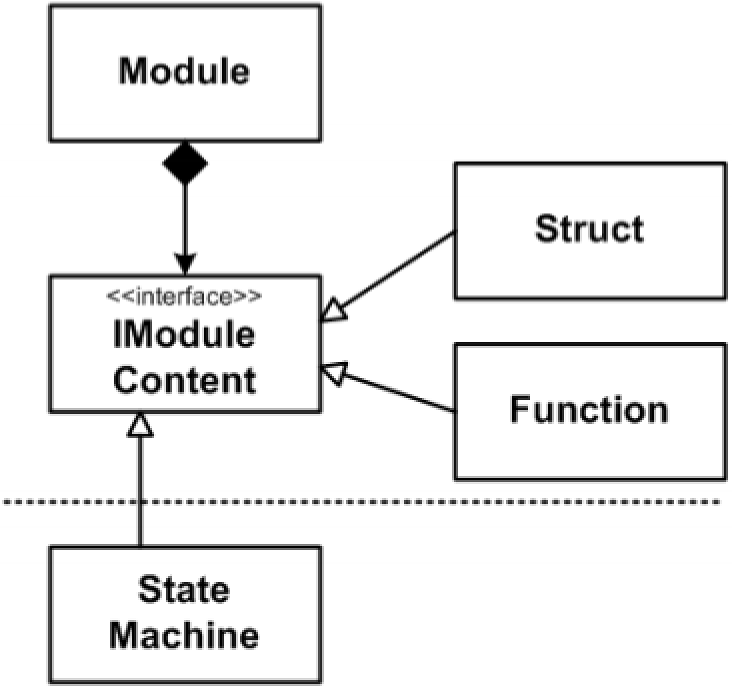
```
task run cyclic prio = 1 every = 2 {
  stateswitch linefollower
    state running
      int32 light = 0;
      light = ecrobot_get_light_sensor
                    (SENSOR_PORT_T::NXT_PORT_S1);
      if ( light < ( WHITE + BLACK ) / 2 ) {
        updateMotorSettings(SLOW, FAST);
      } else {
 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

Exten
ded C

Extension



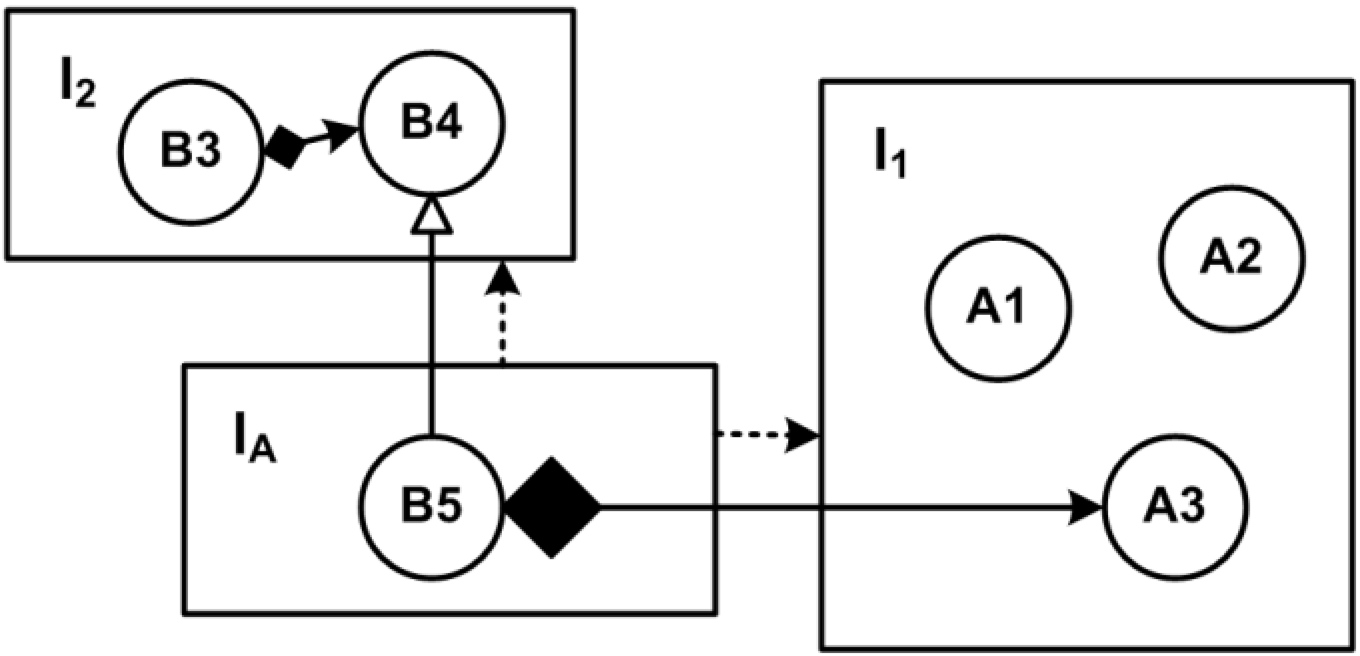
Example

Extended C

Embedding

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

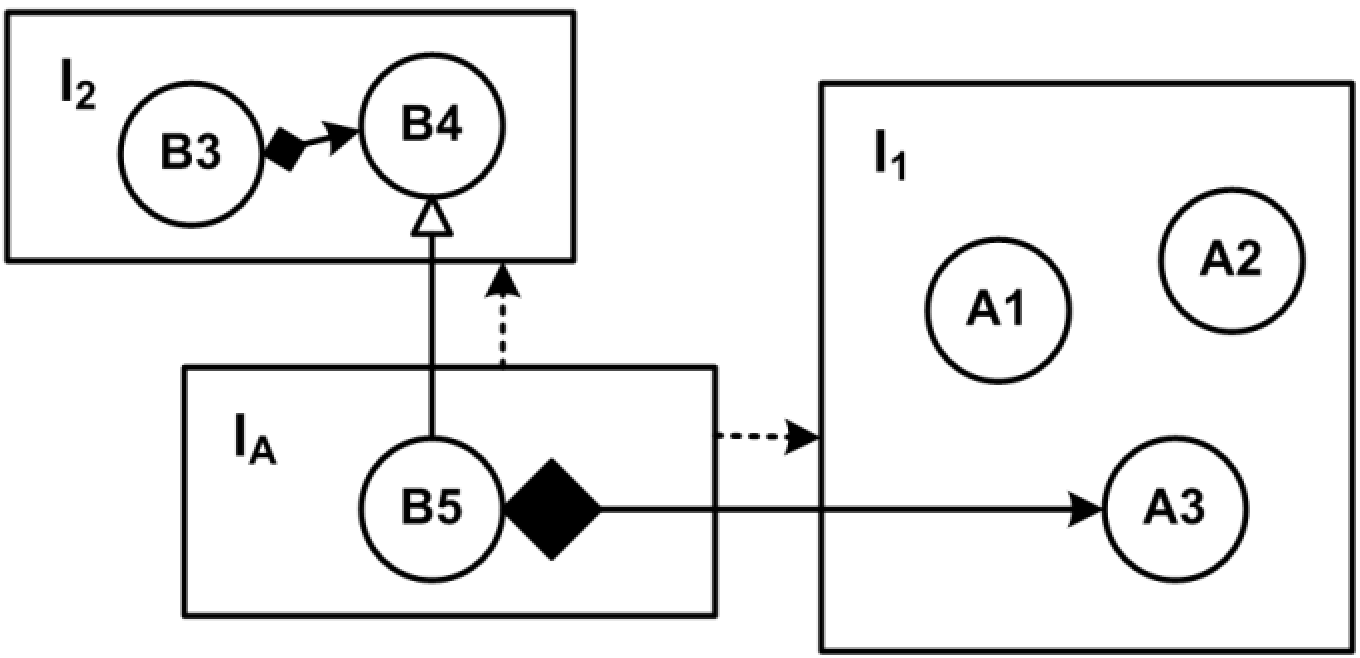
fragment structure



Embedding

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

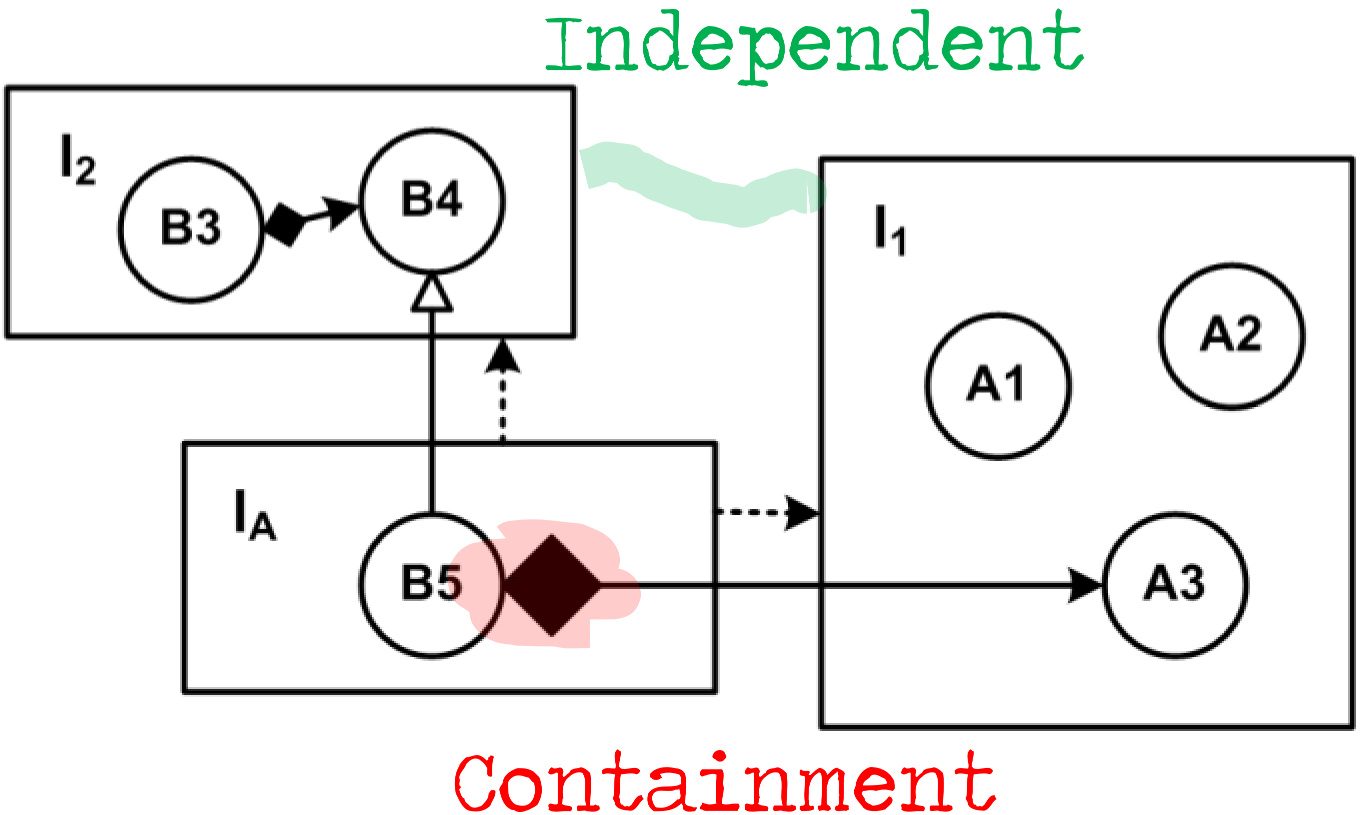
fragment structure



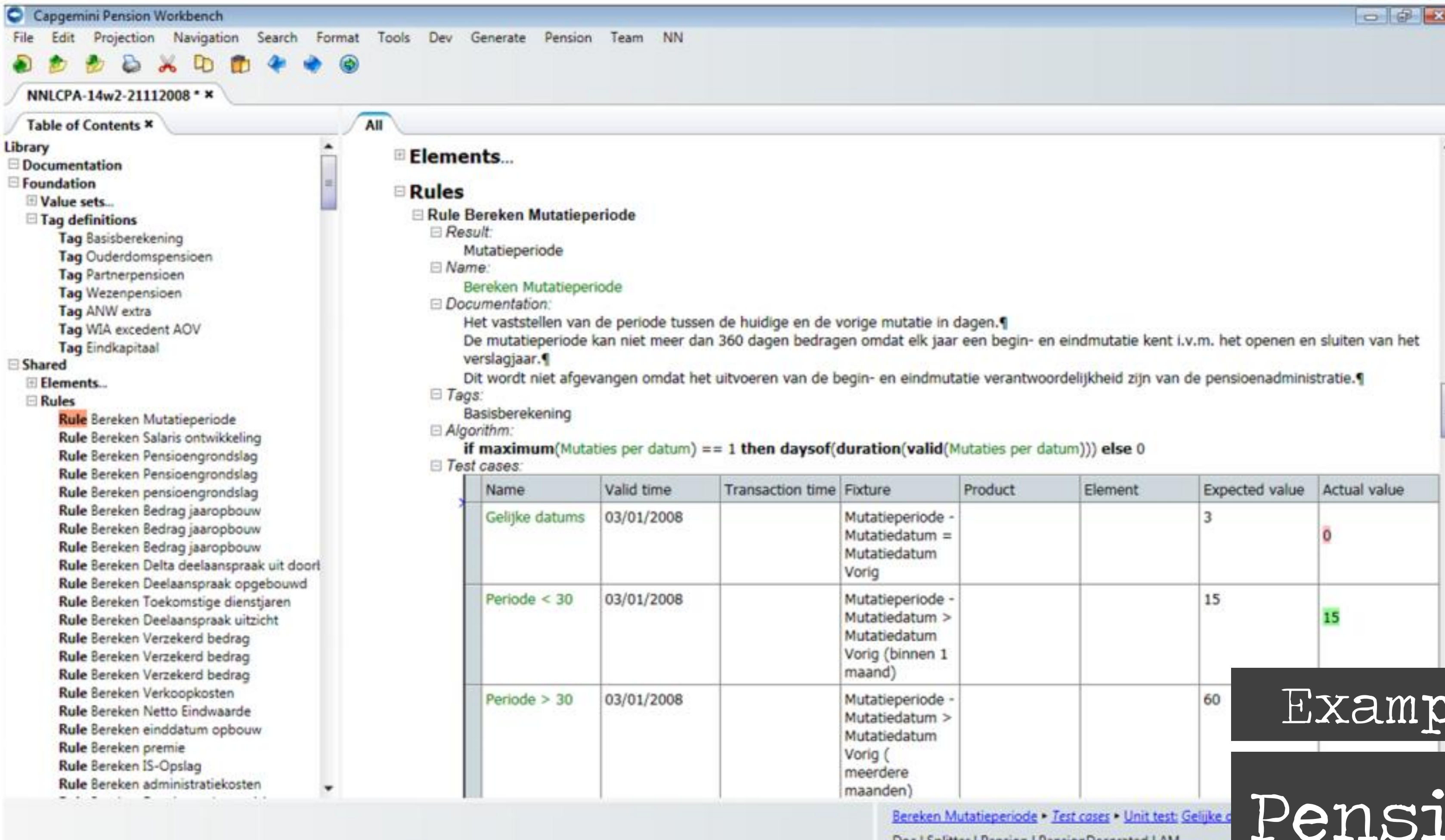
Embedding

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

languages dependencies (rows) · **fragment structure** (columns)



Embedding



Example

Pension Plans

Embedding

<u>Embedding</u> often uses Extension to extend the embedded language to adapt it to its new context.

Concrete Syntax

expressivity	completeness
coverage	paradigms
semantics	modularity
separation of concerns	**concrete syntax**

process

UI for the language!

Important for acceptance by users!

- Textual
- Symbolic
- Tabular
- Graphical

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

Default: Text

Editors simple to build
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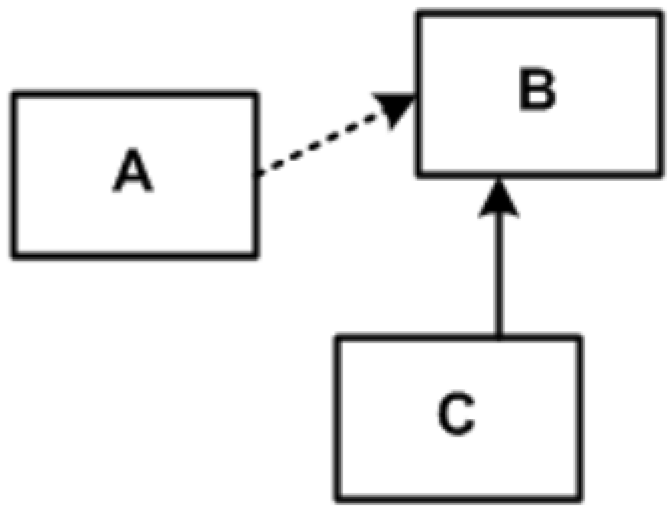
Easy to evolve programs

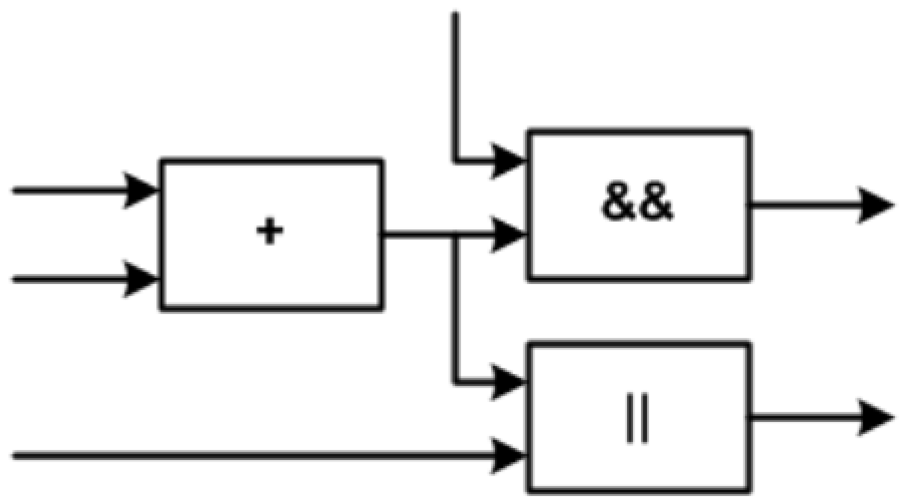
… then add other forms,
if really necessary

Graphical in case...



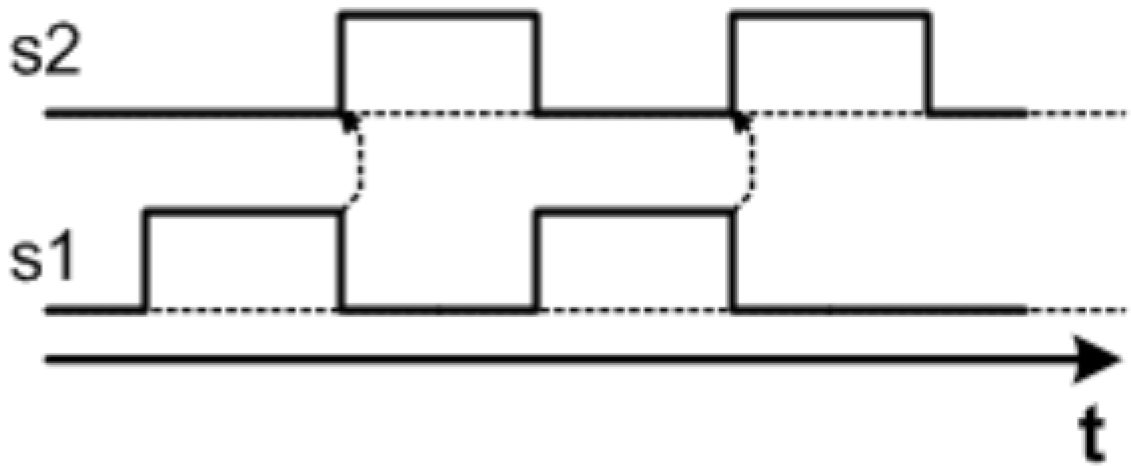
Relationships

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

$$D_x = v^x * \frac{l_x}{100}$$ ¤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

$${}_nE_x = \frac{D_{x+n}}{D_x}$$ ¤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)

$$\bar{a}_{x\overline{n|}} = \ddot{a}_{x\overline{n|}} - 0{,}5 + 0{,}5 * {}_nE_x$$ ¤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
	premiun 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

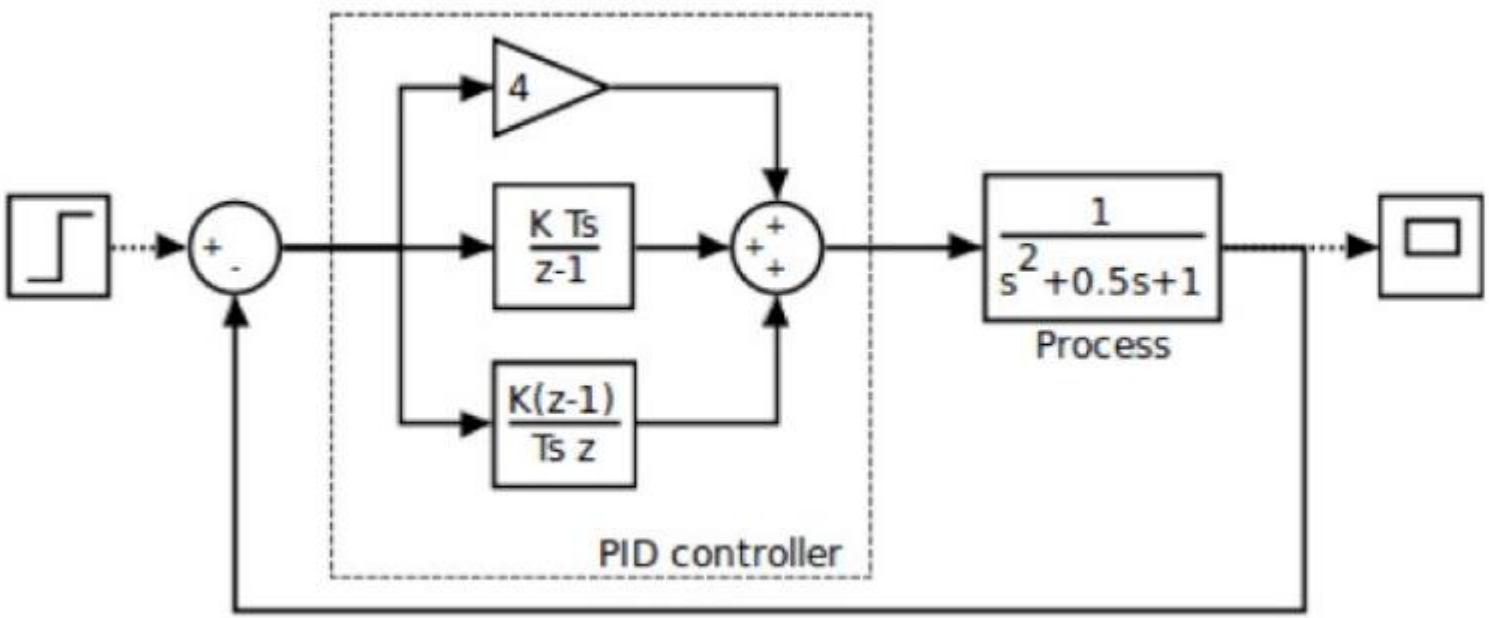
```
c/s interface Decider {
  int decide(int x, int y) pre
}

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

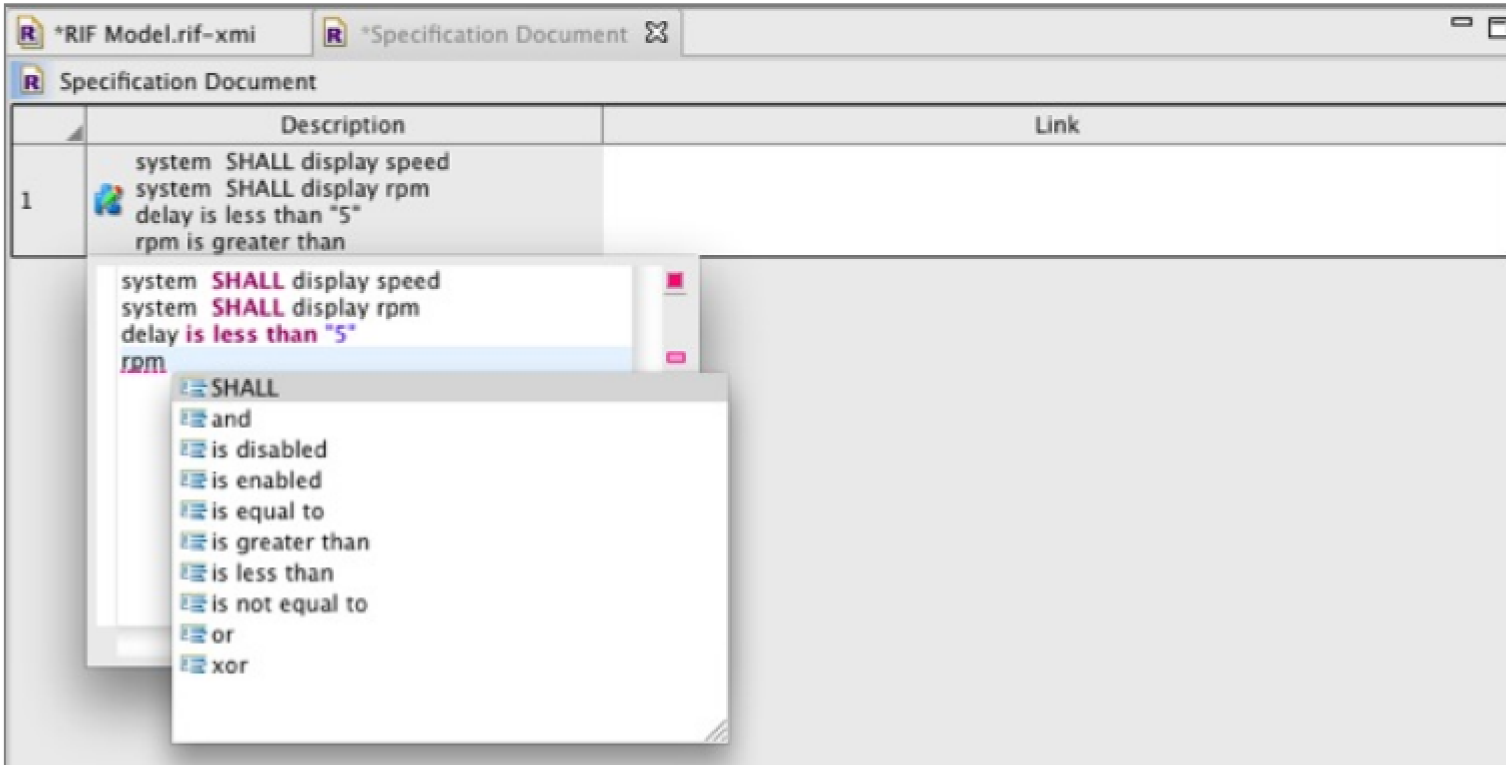
	x == 0	x > 0
y == 0	0	1
y > 0	1	2

```
      ;
    }
}
```

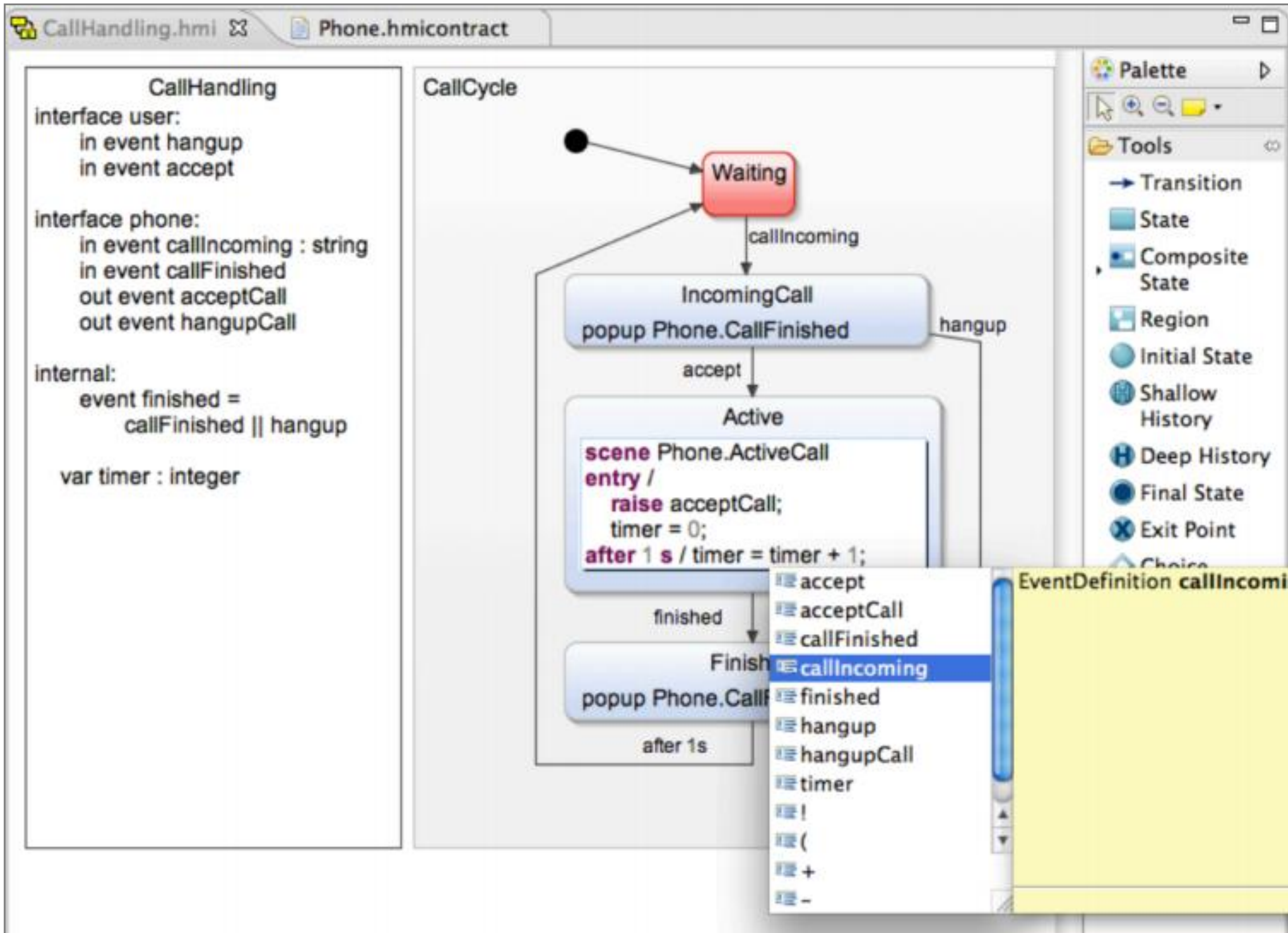
Combinations



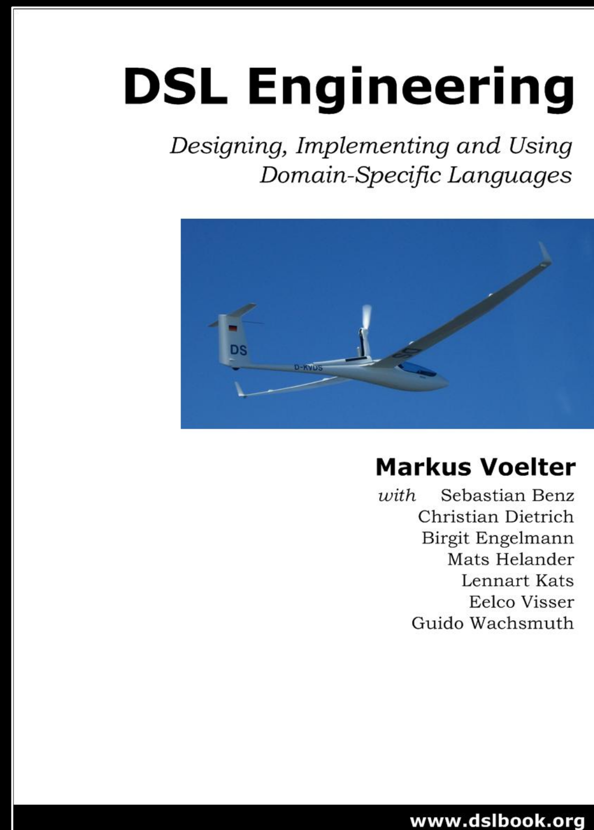
Combinations



Combinations



The End.



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