DSLs
in the context of
Agile

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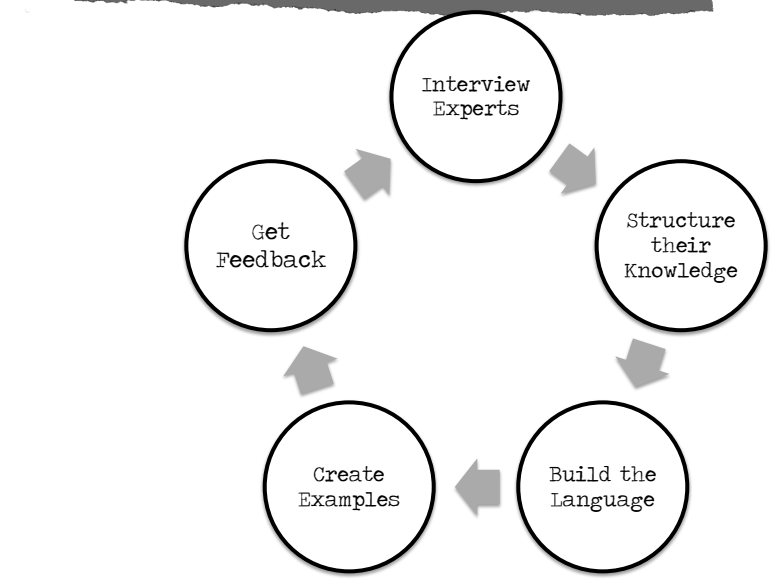
Introduction

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.

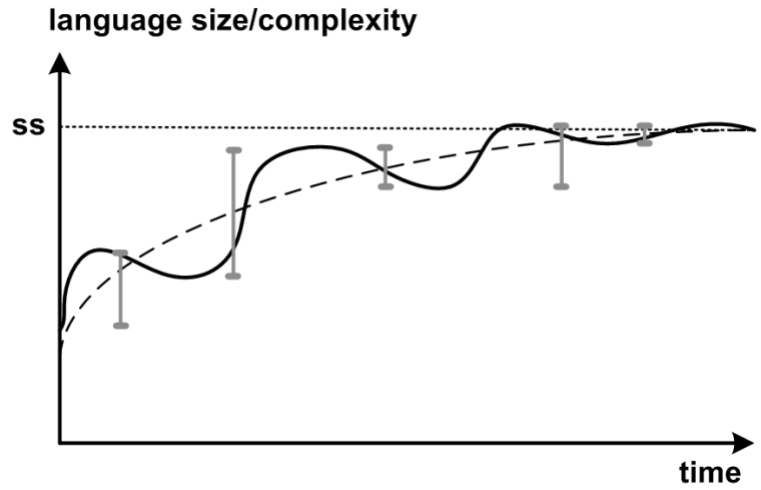
	more in GPLs	more in DSL
Domain Size	large and complex	smaller and well-defined
Designed by	guru or committee	a few engineers and domain experts
Language Size	large	small
Turing-completeness	almost always	often not
User Community	large, anonymous and widespread	small, accessible and local
In-language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

Process

Domain Analysis



Iterate to goal

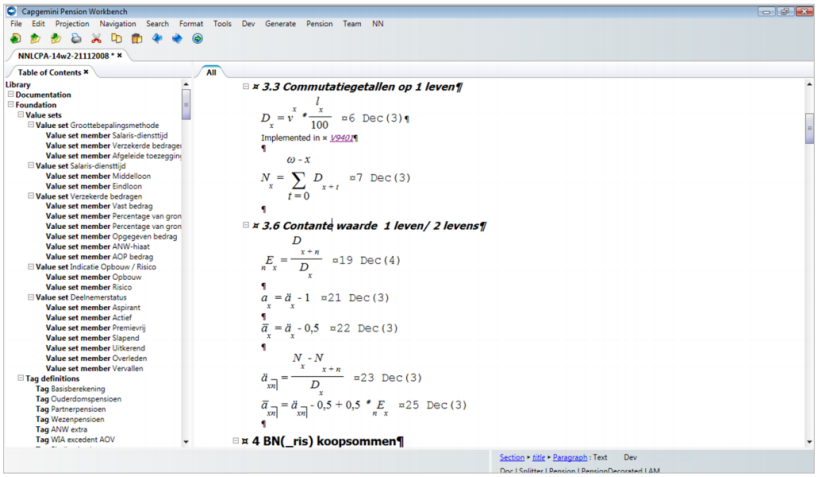


Documentation

Create example-based tutorials!

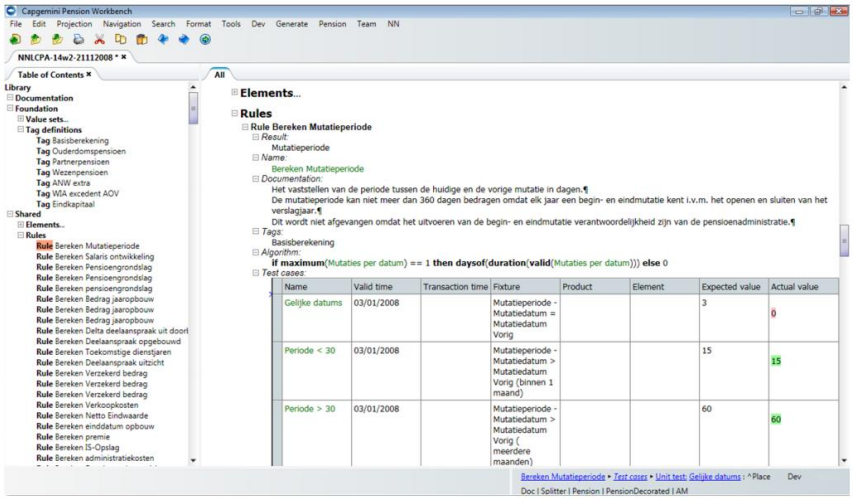
Domain Folks Programming?

Precision vs. Algorithmics!



Example

Pension Plans



Example

Pension Plans

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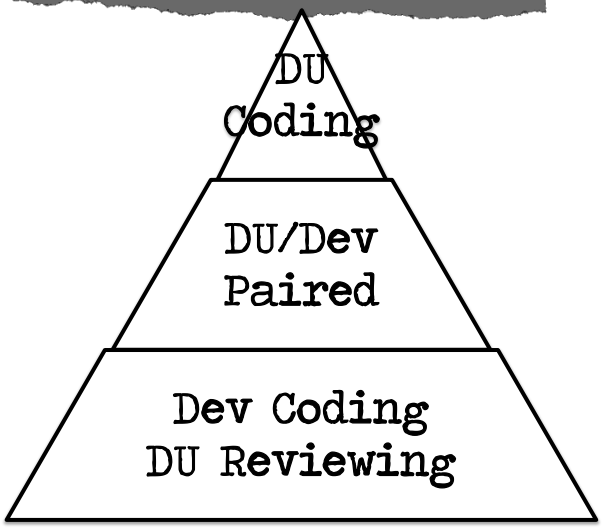
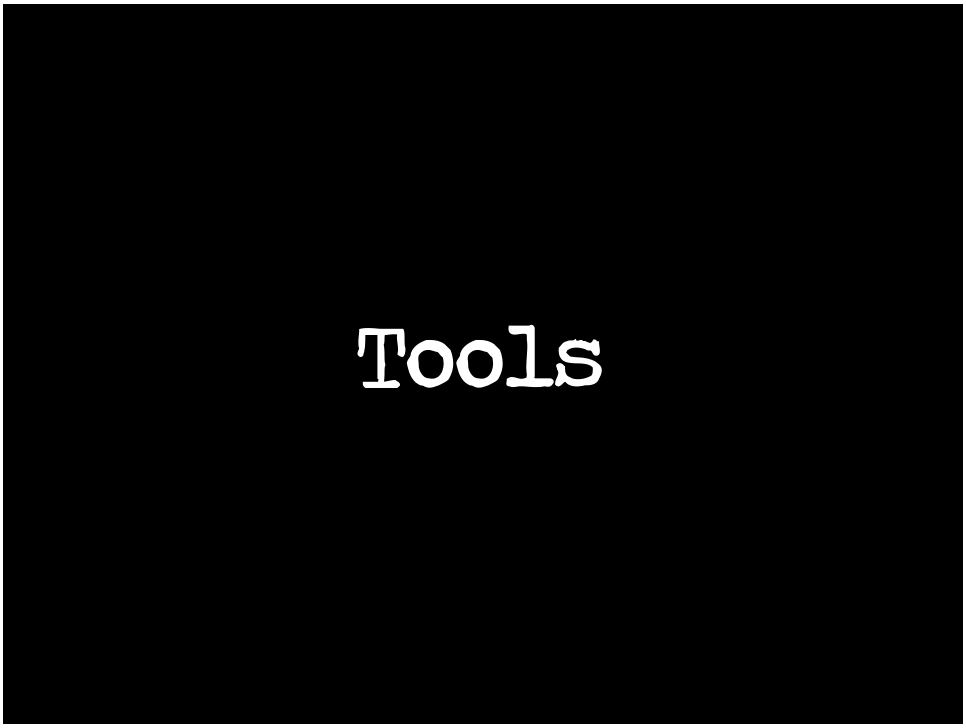


DSL as a Product

Release Plan
Bug Tracker
Testing!
Support
Documentation

Reviews

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


Tools

Language Workbenches

Define, use, evolve and debug a set of integrated langauges

xtext

Language Workbenches

Define, use, evolve and debug a set of integrated langauges

xtext

http://languageworkbenches.net

Expressivity

Shorter
Programs

More
Accessible
Semantics

For a limited
Domain!

Domain Knowledge
encapsulated in
language

Smaller Domain

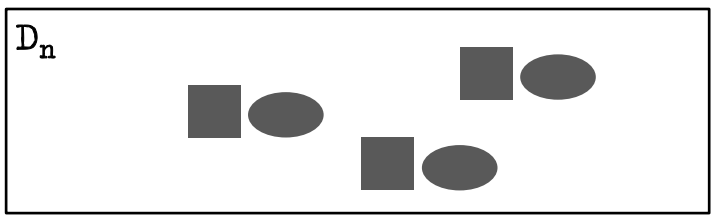
⇩

More Specialized Language

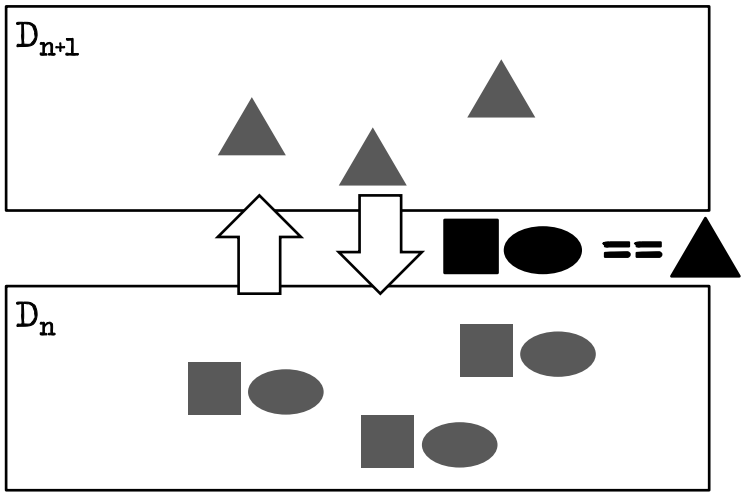
⇩

Shorter Programs

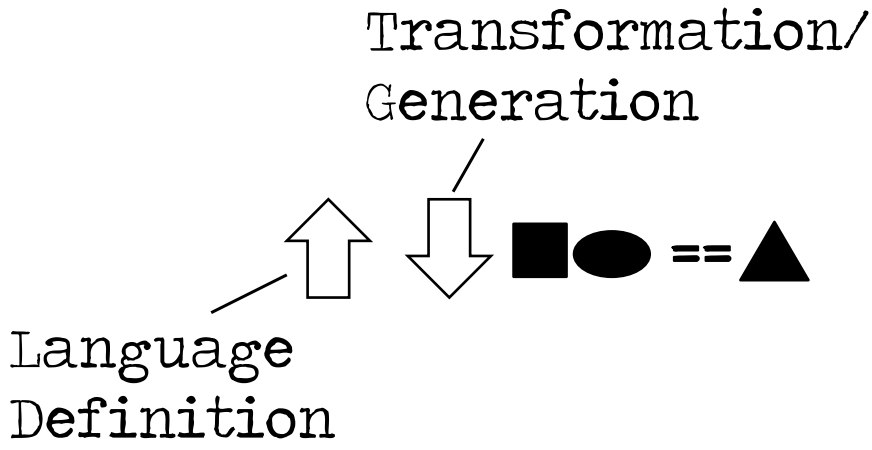
Reification



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

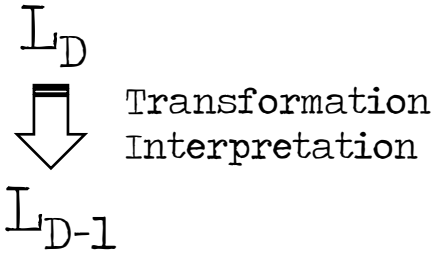
What does it all mean?

Execution Semantics

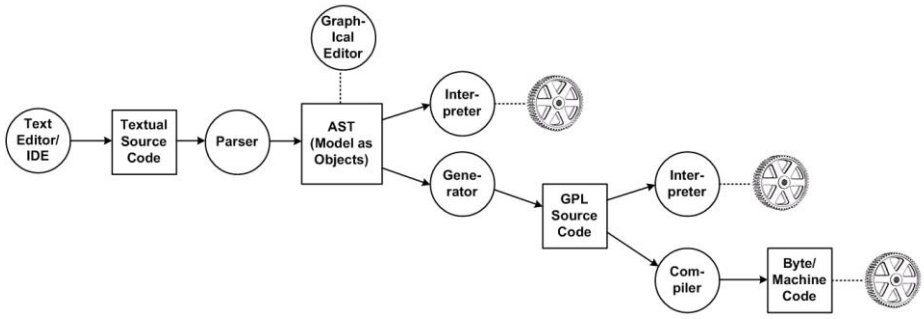
Def: Semantics

… via mapping to lower level

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



Trafo vs. Interpreter



Transformation

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

Interpretation

+ Turnaround Time
+ Runtime Change

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
```

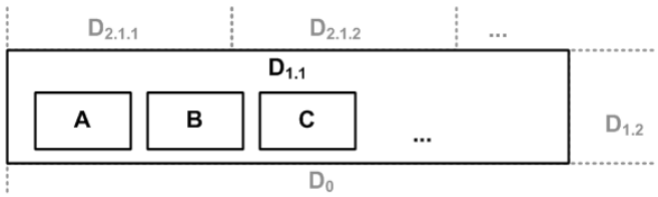
Example

Refrige rators

Separation of Concerns

Several Concerns

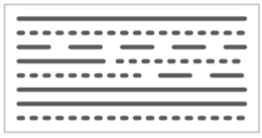
… in one domain



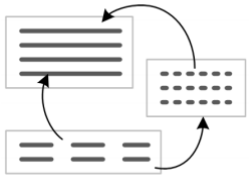
Several Concerns

… in one domain

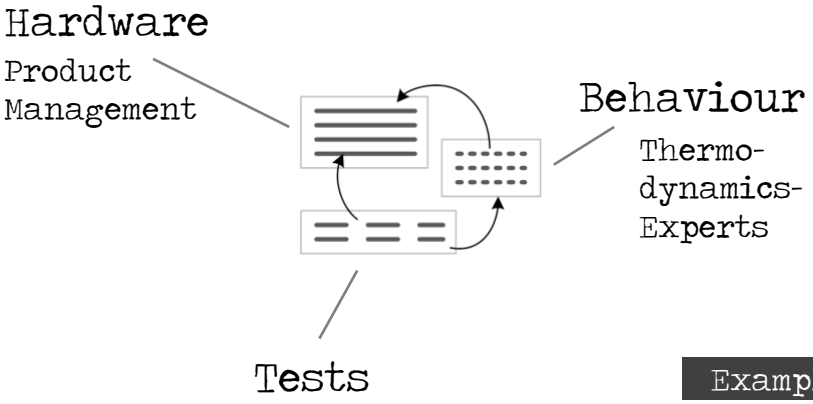
integrated into
one fragment



separated into
several fragments



Viewpoints

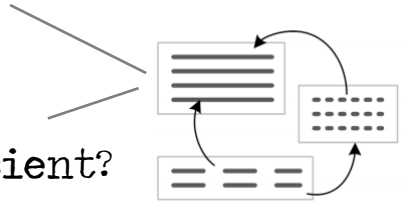


Example

Refrige
rators

Viewpoints

independent

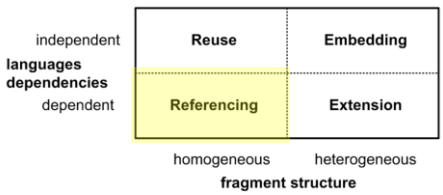


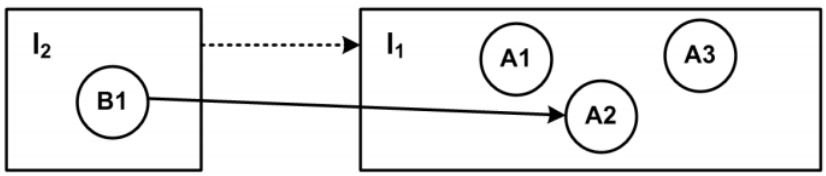
sufficient?

contains all the data for running a meaningful transformation

Language Modularity

Referencing



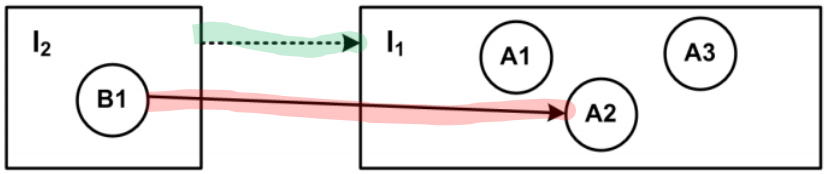


Referencing

languages dependencies	homogeneous	heterogeneous
independent	Reuse	Embedding
dependent	Referencing	Extension

fragment structure

Dependent

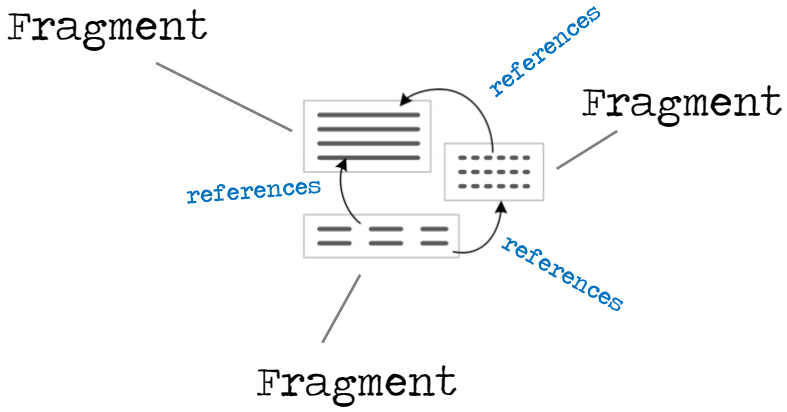


No containment

Referencing

Used in Viewpoints

Referencing



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    }
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        set RC.rcfan->active = true
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        perform rcfanabschalttask after 10 {
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        }
    }


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

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

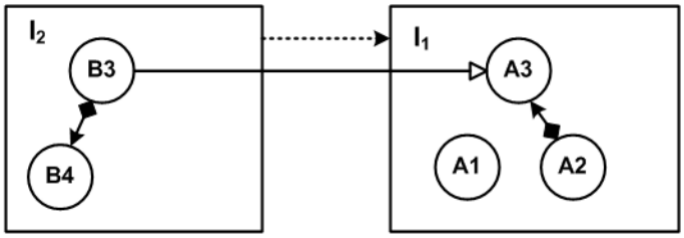
Example

Refrige rators

Extension

languages dependencies	homogeneous	heterogeneous
independent	Reuse	Embedding
dependent	Referencing	Extension

fragment structure



Extension

languages dependencies	homogeneous	heterogeneous
independent	Reuse	Embedding
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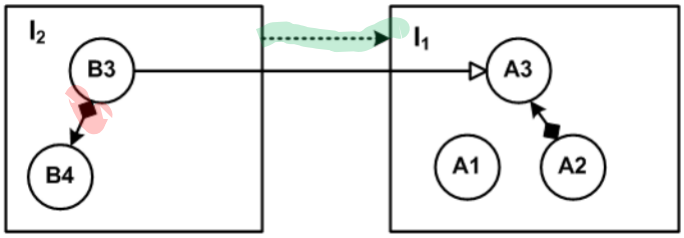
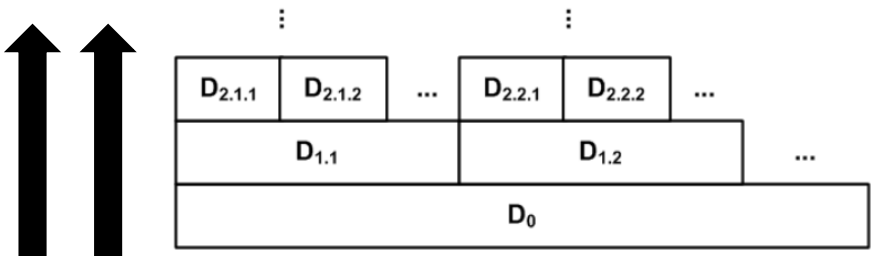
fragment structure

Dependent



Containment

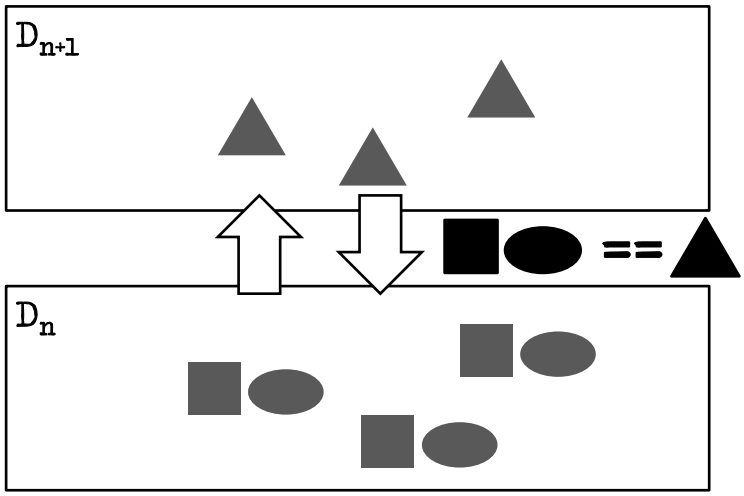
Extension



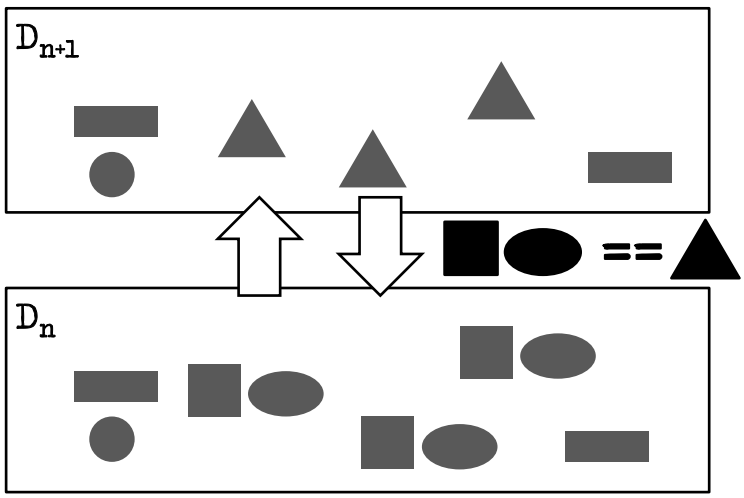
more specialized domains

more specialized languages

Extension

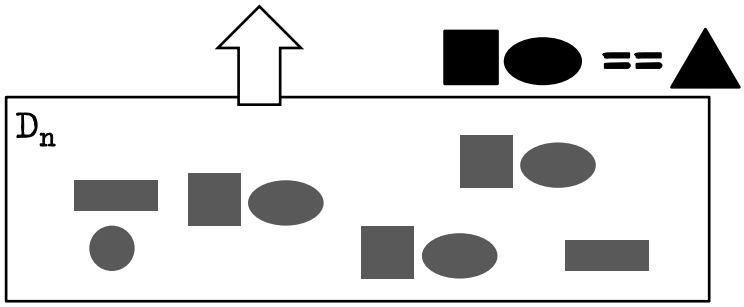


Extension



Extension

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

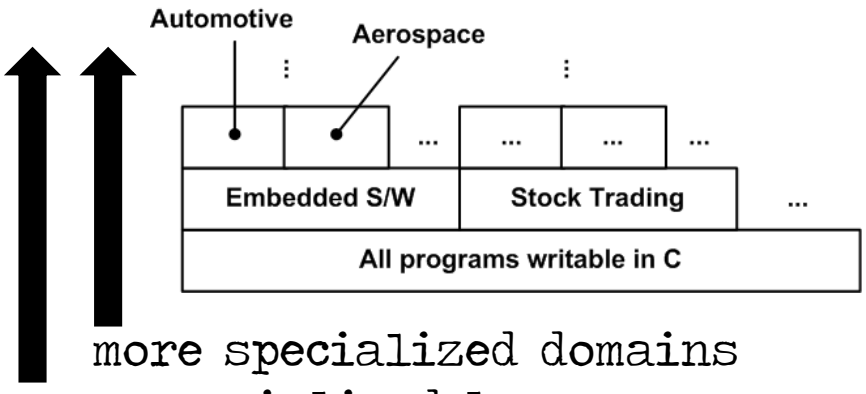


Extension

Drawbacks

tightly bound to base
potentially hard to analyze the combined program

Extension



more specialized domains
more specialized languages

```
module UnitTestDemo from cdesignpaper.unittest imports nothing {

  int32_t main(int32_t argc, int8_t*[ ] argv) {
    return test testMultiply;
  } main (function)

  exported test case testMultiply {
    assert(0) times2(21) == 42;
    if ( 1 > 2 ) {
      fail(1);
    } if

  } testMultiply(test case)

  int8_t times2(int8_t a) {
    return 2 * a;
  } times2 (function)
}
```

```
exported c/s interface Orienter on contract error MultibotMessages.prePostconditionFailed {
  int16_t heading()
    post(0) result >= 0 && result <= 359
  void orientTowards(int16_t heading, uint8_t speed, DIRECTION dir)
    pre(0) heading >= 0 && heading <= 359
}
```


```
exported c/s interface Orienter on contract error MultibotMessages.prePostconditionFailed {
  int16_t heading()
    post(0) result >= 0 && result <= 359
  void orientTowards(int16_t heading, uint8_t speed, DIRECTION dir)
    pre(0) heading >= 0 && heading <= 359
}
```


```
exported component OrienterImpl extends nothing {
  ports:
    provides Orienter orienter
    requires EcRobot_Compass compass
    requires EcRobot_Motor motorLeft
    requires EcRobot_Motor motorRight
  contents:
    field int16_t[5] headingBuffer

    void orienter_orientTowards(int16_t heading, uint8_t speed, DIRECTION dir) <-
        op orienter.orientTowards {
      int16_t currentDir = compass.heading();
      if ( dir == COUNTERCLOCKWISE ) {
        motorLeft.set_speed(-1 * ((int8_t) speed));
        motorRight.set_speed(((int8_t) speed));
        while ( currentDir != heading ) { currentDir = compass.heading(); } while
      } else {
        motorLeft.set_speed(((int8_t) speed));
        motorRight.set_speed(-1 * ((int8_t) speed));
        while ( currentDir != heading ) { currentDir = compass.heading(); } while
      } if
      motorLeft.stop();
      motorRight.stop();
    }

    int16_t orienter_heading() <- op orienter.heading {
      return compass.heading();
    }
}
```

```
exported test case testDriveTrain {
  initialize instances;
  assert(0) dt.currentSpeed() == 0;
  dt.driveContinouslyForward(50);
  dt.stop();
  validate mock motorLeft;
  validate mock motorRight;
} testDriveTrain(test case)
```

```
instance configuration instances extends nothing {
  instances:
  instance MotorLeftMock motorLeft
  instance MotorRightMock motorRight
  instance DriveTrainImpl driveTrain
  instance EcUtil util
  connectors:
  connect driveTrain.motorLeft to motorLeft.motor
  connect driveTrain.motorRight to motorRight.motor
  connect driveTrain.util to util.util
  adapter:
  << ... >>
}
```

```
mock component MotorLeftMock {
  report messages: true
  ports:
    provides EcRobot_Motor motor
  expectations:
    total no. of calls is 2
    sequence {
      0: motor.set_speed {
          0: parameter speed: speed == 50
        }
      1: motor.stop
    }
}
```

```
mock component MotorRightMock {
  report messages: true
  ports:
    provides EcRobot_Motor motor
  expectations:
    total no. of calls is 2
    sequence {
      0: motor.set_speed {
          0: parameter speed: speed == 50
        }
      1: motor.stop
    }
}
```

```
void testBasicUnits() {
  int8_t/N n = 3 N;
                      -2
  int8_t/N n3 = 3 kg m s ;

  int8_t/m length;
  int8_t/s time;
                -1
  int8_t/[m s ] speed = length / time;

  int8_t/v thisShouldNotWork = length + time;

  length l1 = length + length;
  length l2 = length * 33;
  length l3 = length / 3;
  length l4 = length + 3;
} testBasicUnits (function)
```

```
verifiable
statemachine Counter {
  in start() <no binding>
     step(int[0..10] size) <no binding>
  out someEvent(int[0..100] x, boolean b) => handle_someEvent
      resetted() => resetted
  vars int[0..100] 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
```

Testing DSLs

Syntax

```
@RunWith(XtextRunner2.class)
@InjectWith(DomainmodelInjectorProvider.class)
public class ParserAndLexerTest extends XtextTest {
	@Test
	public void id(){
		testTerminal("bar", /* token stream: */ "ID");
		testTerminal("bar3", /* token stream: */ "ID");
		testTerminal("_bar_", /* token stream: */ "ID");
		testTerminal("$bar$", /* token stream: */ "ID");

		testNotTerminal("3bar", /* unexpected */ "ID");
		testNotTerminal("#bar", /* unexpected */ "ID");

		// token streams with multiple token
		testTerminal("foo.bar", "ID", "'.'", "ID");
		testTerminal("foo.*", "ID", "'.'", "'*'");
	}

	@Test
	public void qualifiedName(){
		testParserRule("foo.bar", "QualifiedName");
		testParserRuleErrors("3foo.bar", "QualifiedName", "extraneous input '3'");
	}

	@Test
	public void qualifiedNameWithWildcard(){
		testParserRule("foo.*", "QualifiedNameWithWildCard");
	}
}
```

http://code.google.com/a/eclipselabs.org/p/xtext-utils/wiki/Unit_Testing

Type System

```
model subtyping

calc int t1 = 2;       // works
calc int t2 = 2.2;     // error: float cannot be assigned to int
calc float t3 = 2.2;   // works
calc float t4 = 2;     // works; int can be assigned to float
calc int t5 = 2 + 2;   // works; type of plus is int
calc int t6 = 2 + 2.3; // error: common type of 2 and 2.3 is float
                                                    signed to int
```

incompatible type Int and Float (on a Formula)

Press 'F2' for focus

tests

```
@Test
public void testTArray() throws Exception {
    testFileNoSerializer("4-array.expr2");
    assertConstraints( issues.errorsOnly().sizeIs(1) );
    assertConstraints( issues.forType(Formula.class).named("anotherOne2").
            theOneAndOnlyContains("incompatible") );
}
```

Type System

```
module Dummy from tests.ts.core.tests1 imports nothing {

  void dummy() {
    int8_t[2] andererArray = {10, 20};
    int8_t[3] intarr = {10, 20, 30};
    int8_t[2] two = {1, 2, 3};
    float[2] fa = {1, 2};
    int8_t[2] ia = {1.1, 2.1};
    int8_t* intp = andererArray;
    int8_t* intp2 = intarr;
    int8_t[ ] xx = {1, 2.1, "Hello"};
    int8_t x = xx[2];
    float ff = xx[2];
    int8_t fi = fa[2];

  } dummy (function)
}
```

Type System

```
nodes
  ( [ <check types module Dummy from tests.ts.core.tests1 imports nothing { > ] )

                  void dummy() {
                    int8_t[2] andererArray = {10, 20};
                    int8_t[3] intarr = {10, 20, 30};
                    int8_t[2] two = <node {1, 2, 3} has error>;
                    float[2] fa = {1, 2};
                    int8_t[2] ia = <node {1.1, 2.1} has error>;
                    int8_t* intp = andererArray;
                    intp = <node fa has error>;
                    int8_t* intp2 = intarr;
                    int8_t[ ] xx = <node {1, 2.1, "Hello"} has error>;
                    int8_t x = xx[2];
                    float ff = xx[2];
                    int8_t fi = <node fa[2] has error>;

                  } dummy (function)
                }
```

Type System

```
  ( [ <check types module Dummy from tests.ts.core.tests1 imports nothing { > ] )

                  exported test case arrayAccessPrioTest {
                    int8_t[2] array = {10, 20};
                    <arrayAccessPrioTest1  array[1]>;
                    <arrayAccessPrioTest2  array[1] * 2>;
                    int8_t i = 2;
                    <arrayAccessPrioTest3  array[1] * i++>;

                    <arrayAccessPrioTest4  -array[1]>;
                  } arrayAccessPrioTest(test case)
                }

test methods
  test prioTestArrayAccess {
    assert true arrayAccessPrioTest1.isInstanceOf(ArrayAccessExpr);
    assert true arrayAccessPrioTest2.isInstanceOf(MultiExpression);
    assert true arrayAccessPrioTest2.left.isInstanceOf(ArrayAccessExpr);
    assert true arrayAccessPrioTest2.right.isInstanceOf(NumberLiteral);
    assert true arrayAccessPrioTest3.isInstanceOf(MultiExpression);
    assert true arrayAccessPrioTest3.left.isInstanceOf(ArrayAccessExpr);
    assert true arrayAccessPrioTest3.right.isInstanceOf(PostIncrementExpression);
    assert true arrayAccessPrioTest4.isInstanceOf(UnaryMinusExpression);
    assert true arrayAccessPrioTest4.expression.isInstanceOf(ArrayAccessExpr);
  }
```

Semantics

```
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
```

Semantics

```
re.pointers imports nothing {

typedef (int8_t, int8_t)=>(int8_t) as twoIntArgsReturningInt;

int8_t add(int8_t x, int8_t y) {
  return x + y;
} add (function)

exported test case testFC {
  globalRef = :add;
  int8_t res = globalRef(1, 2);
  assert(0) res == 3;

  (int8_t, int8_t)=>(int8_t) localRef;
  localRef = :add;
  int8_t localres = localRef(10, 22);
  assert(1) localres == 32;
  assert(2) -anotherHOF(:add) == -9;
  assert(3) higherOrderFunction(globalRef) == 3;
  assert(4) higherOrderFunction(:add) == 3;
  assert(5) anotherHOF(:add) == 9;

} testFC(test case)
```

```
int8_t higherOrderFunction((int8_t, int8_t)=>(int8_t) fun) {
  return fun(1, 2);
} higherOrderFunction (function)

int8_t anotherHOF(twoIntArgsReturningInt fun) {
  return fun(4, 5);
} anotherHOF (function)
}
```

Editor

Default × TestCreatingNewVariable × InitializingNewVariable ×

```
Editor test case InitializingNewVariable
description: no description
before: Variables:
          <cell var <no name> : <no alias>>
result: Variables:
          var myVariale : boolean
code:
  type "myVariable"
  press keys <any>+<VK_TAB>;
  press keys <ctrl>+<VK_SPACE>;
  type "boo"
  press keys <any>+<VK_ENTER>;
```

The End.

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

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