Working with multiple languages

Why and How

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based on the DSL Engineering book and the mbeddr tool

I think there is
a world market
for maybe five
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Thomas J. Watson

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Bill Gates

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John C. Dvorak

Why would you want support for (modular) language composition?

You can always "cobble together" a few separate DSLs.

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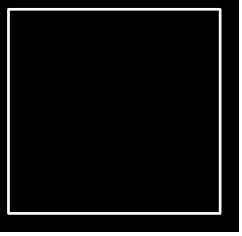
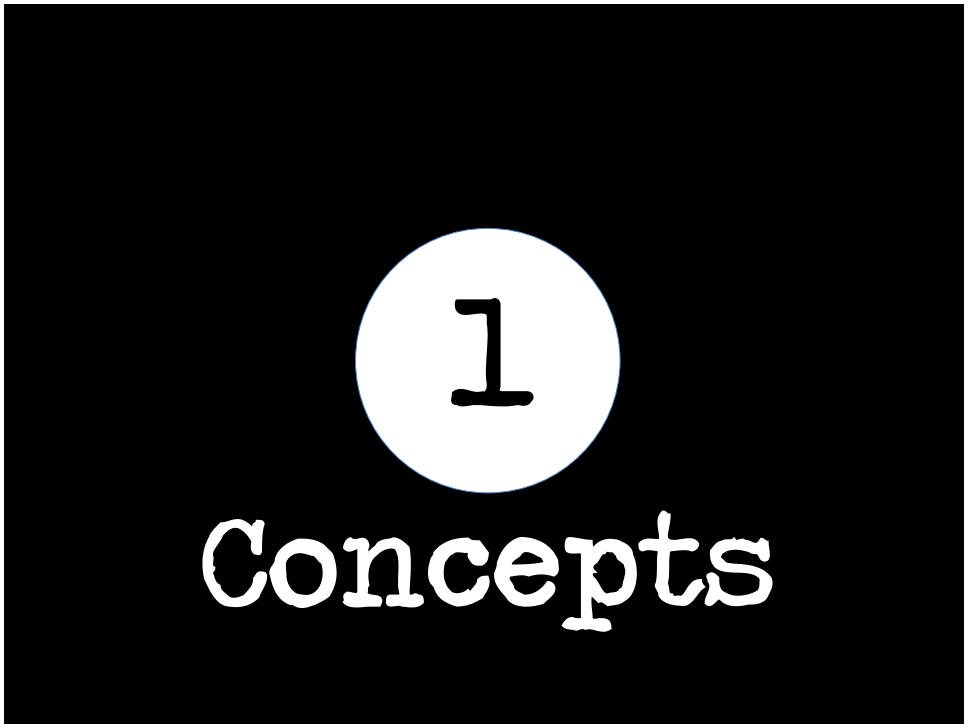


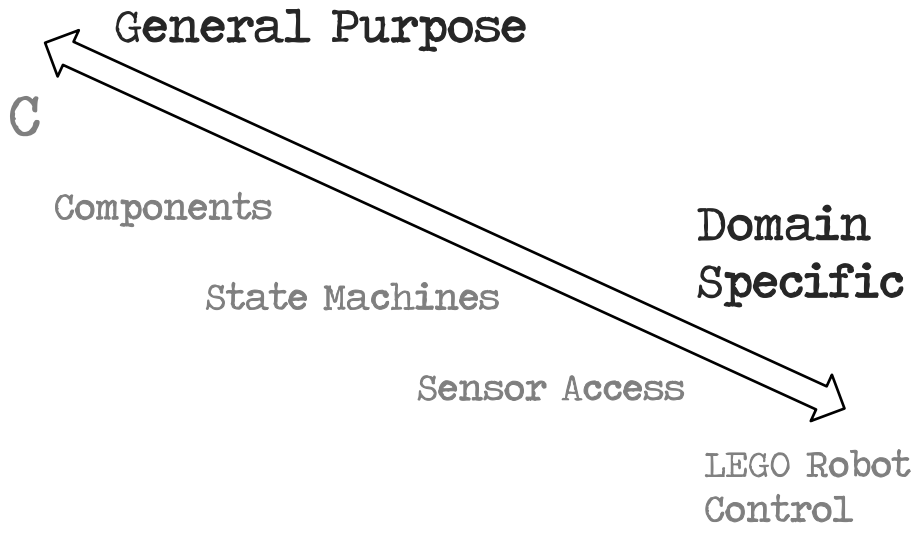
Anonymous

(1) Concepts
(2) Tools
(3) Demo

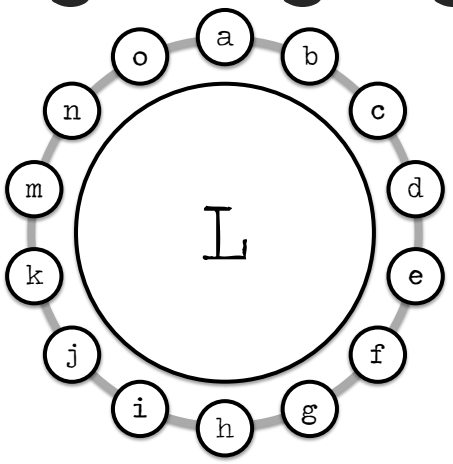


Introduction

	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

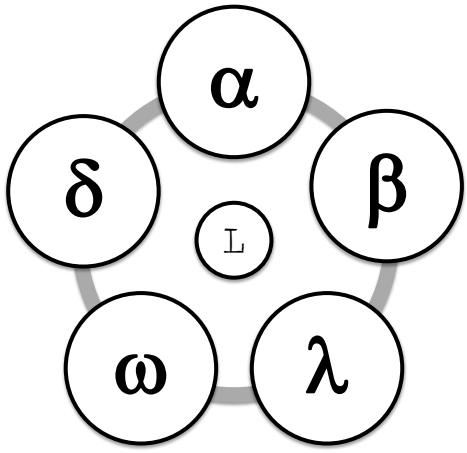


Big Language



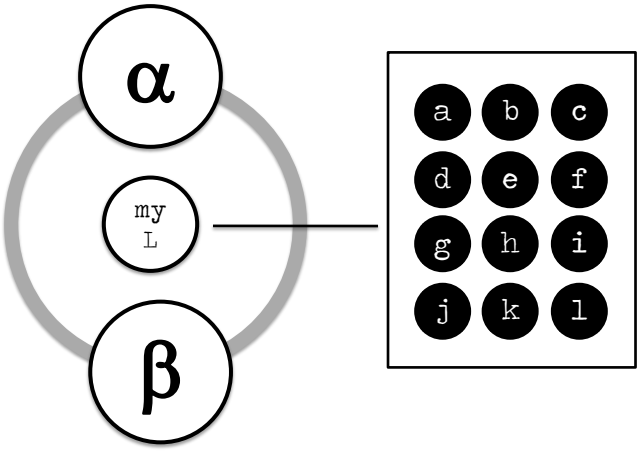
with **many** first class concepts!

Small Language



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

Modular Language



with many optional,
composable modules

Shorter
Programs

More
Accessible
Semantics

For a limited
Domain!

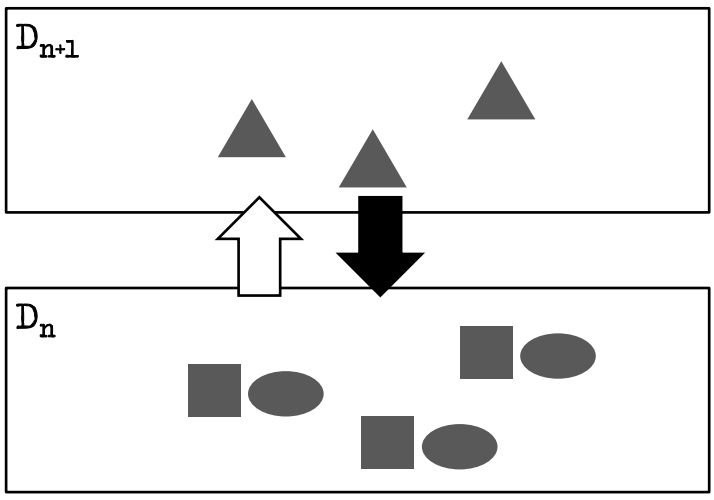
Domain Knowledge
encapsulated in
language

Multi-Stage Transformation

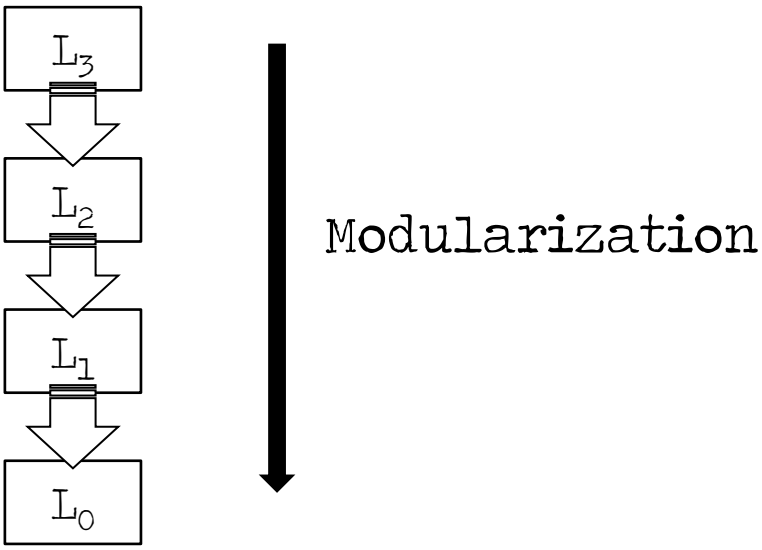
What does it all mean?

Execution Semantics

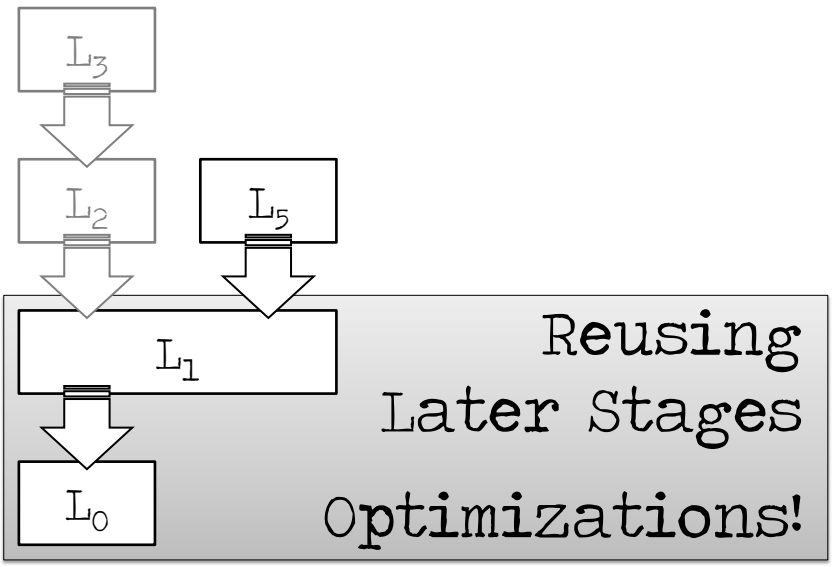
Transformation



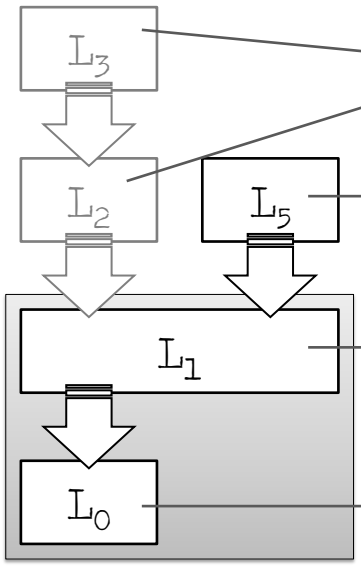
Multi-Stage



Multi-Stage: Reuse



Multi-Stage: Reuse

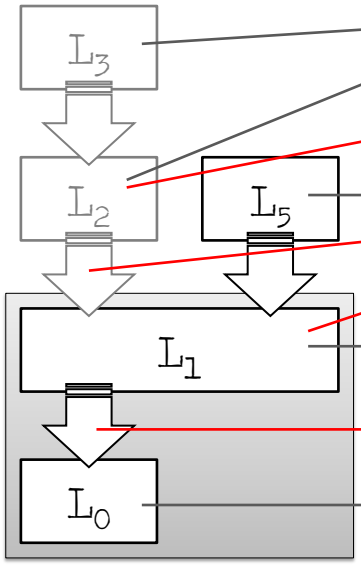


Robot Control
State Machine
Components
C (MPS tree)
C Text

Example

Exten
ded C

Multi-Stage: Reuse

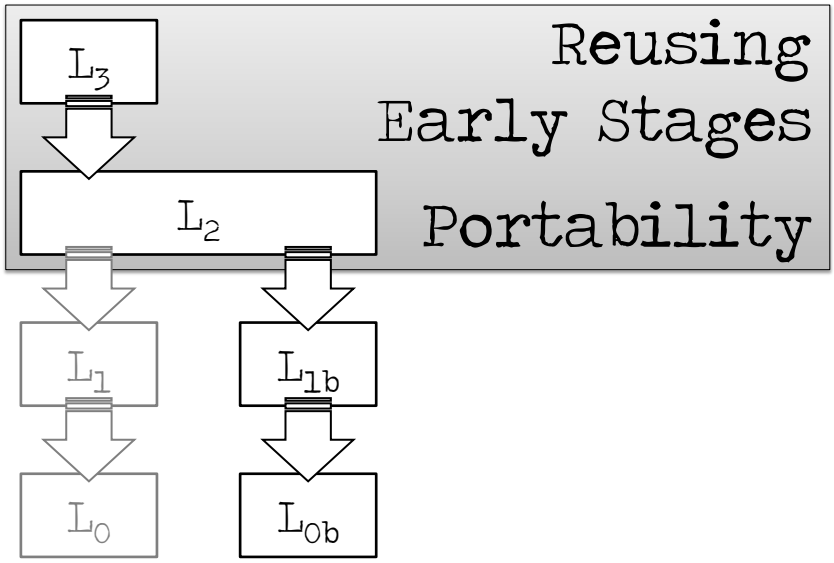


Robot Control
State Machine
Consistency
Model Checking
Components
Efficient Mappings
C Type System
C (MPS tree)
Syntactic
Correctness,
Headers
C Text

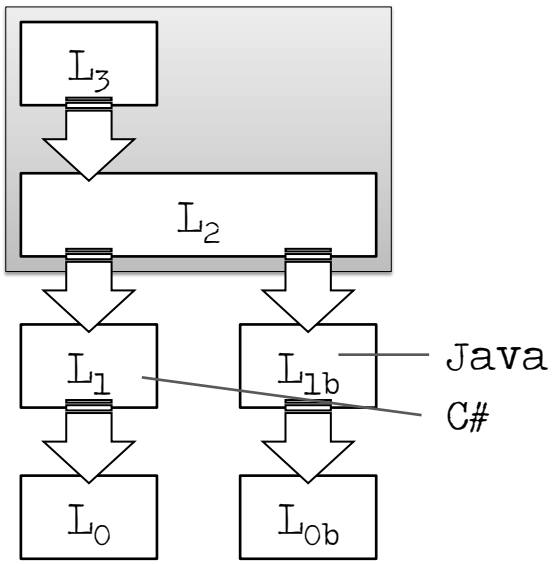
Example

Exten
ded C

Multi-Stage: Reuse



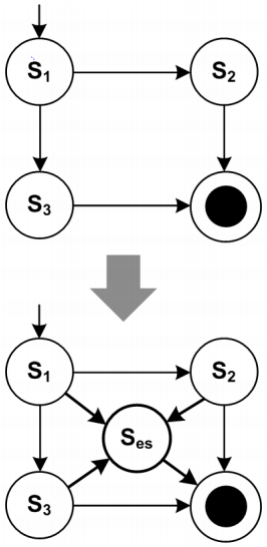
Multi-Stage: Reuse



Example

Exten
ded C

Multi-Stage: Preprocess

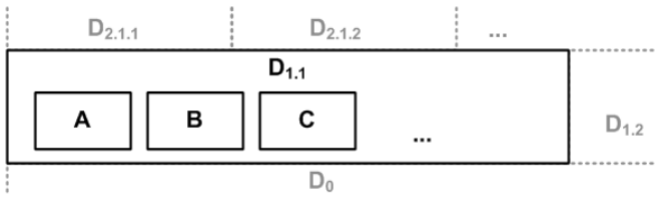


Adding an optional, modular emergency stop feature

Separation of Concerns - Referencing

Several Concerns

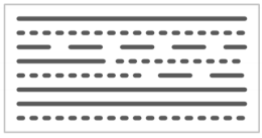
… in one domain



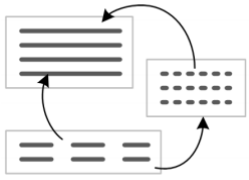
Several Concerns

… in one domain

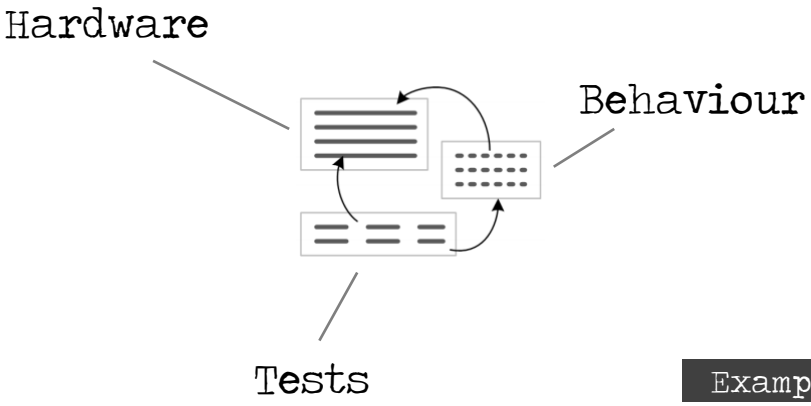
integrated into one fragment



separated into several fragments



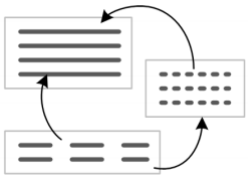
Viewpoints



Example

Refrige rators

Viewpoints: Why?

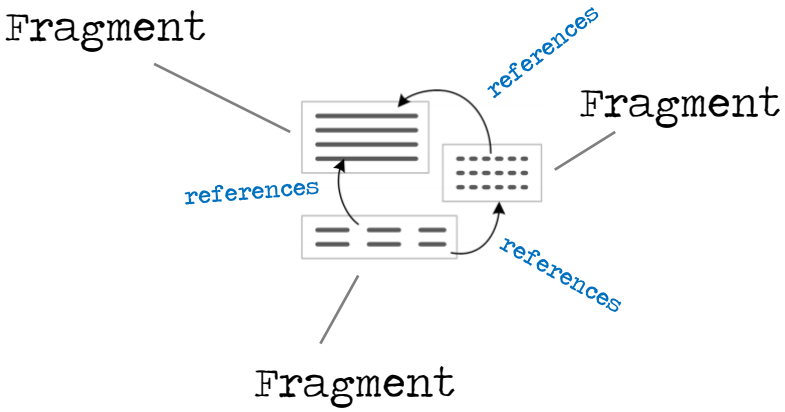


Sufficiency

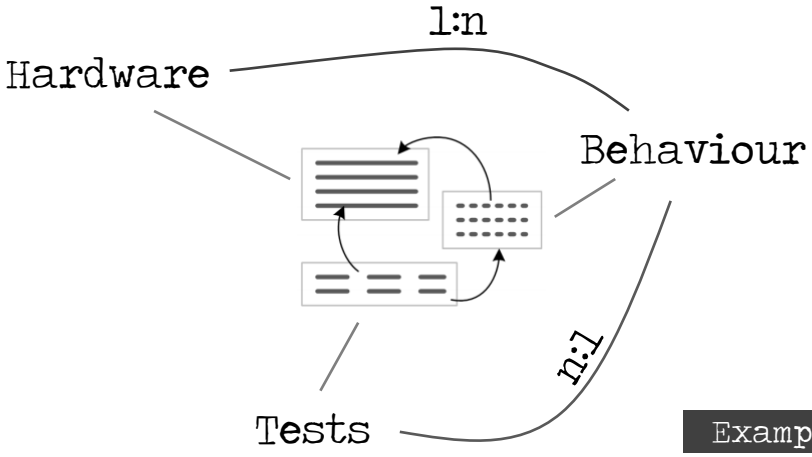
Different Stakeholders

Different Steps in Process - VCS unit!

Referencing



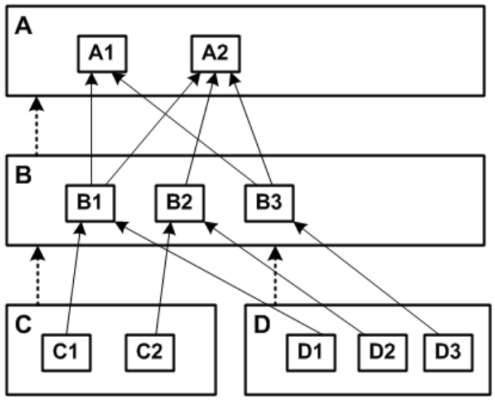
Viewpoints



Example

Refrige rators

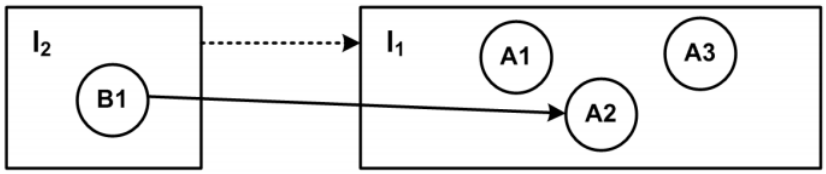
Progressive Refinement



Referencing

languages dependencies	homogeneous	heterogeneous
independent	Reuse	Embedding
dependent	Referencing	Extension

fragment structure



Referencing

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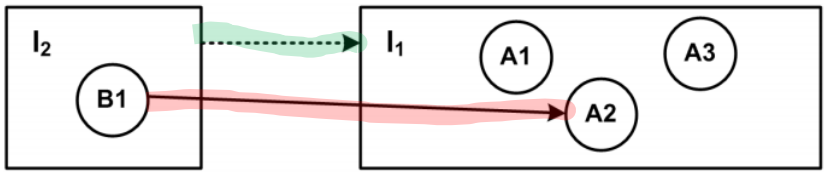
fragment structure

Dependent



No containment

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
        }
    }
```

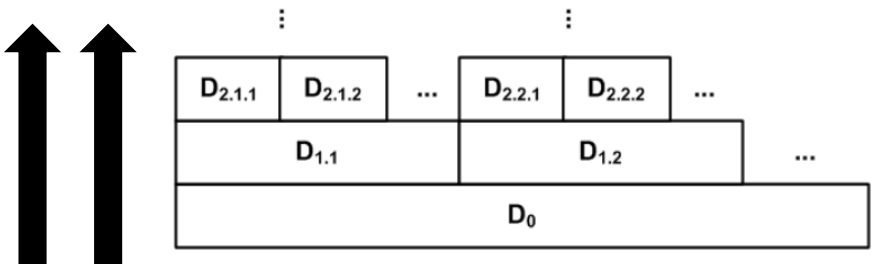
```
prolog {
    set RC->accumulatedRuntime = 80
}

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

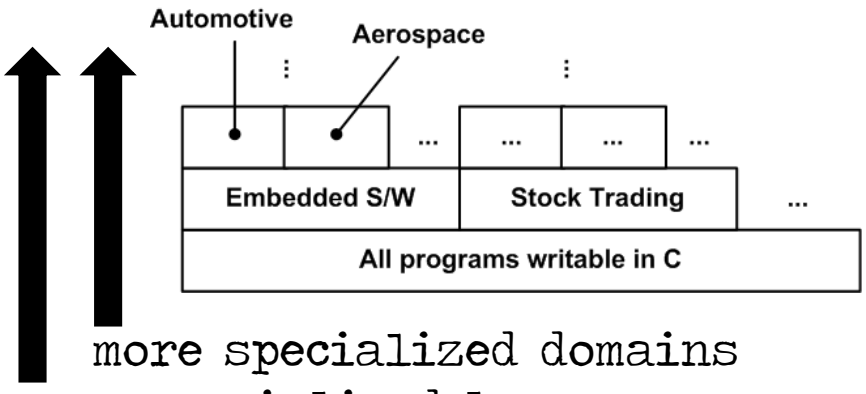
Growing a Language - Extension

Extension



more specialized domains
more specialized languages

Extension



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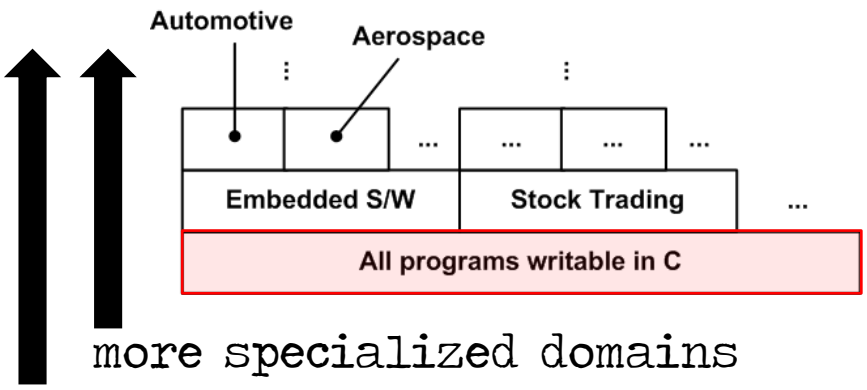

more specialized domains
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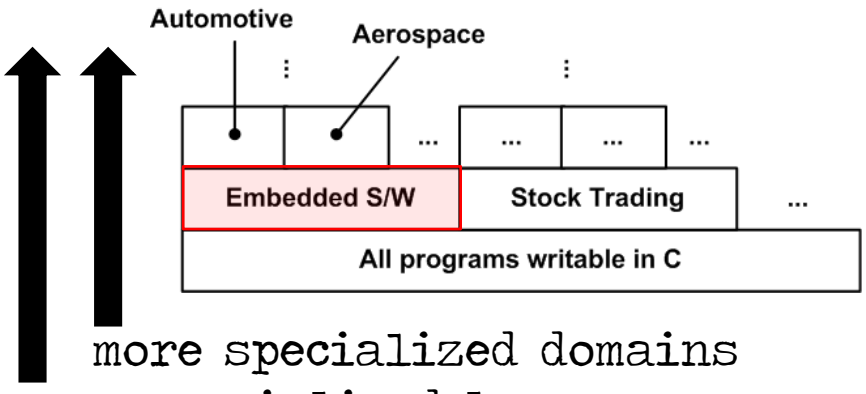

more specialized domains
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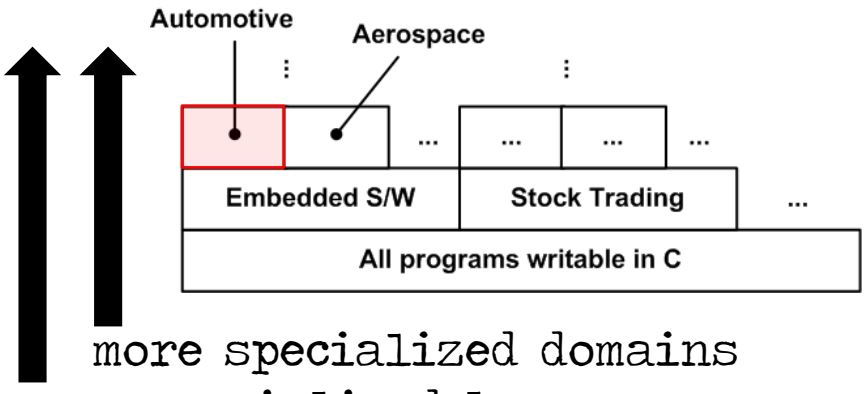

more specialized domains
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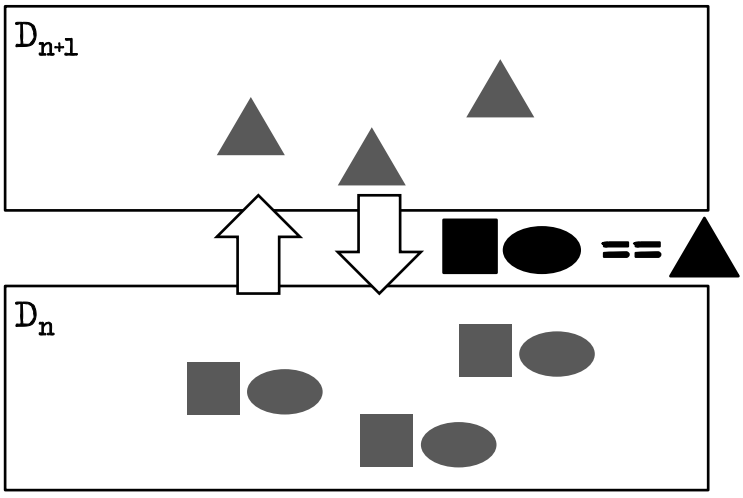
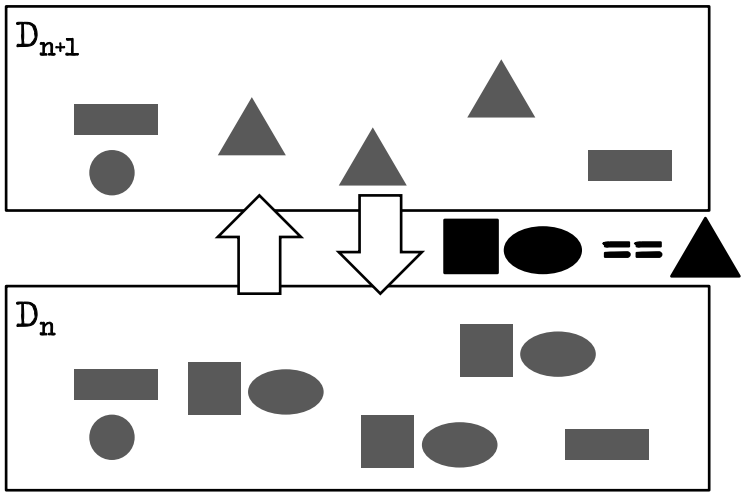
Extension

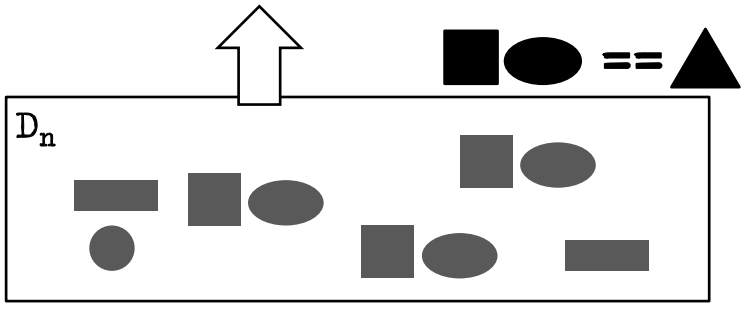


Extension



Extension

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



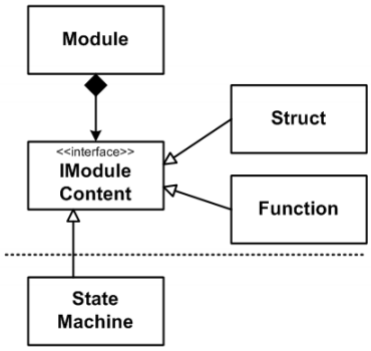
Extension

```
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

Extended C

```
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!

Extension

Drawbacks

tightly bound to base
potentially hard to analyze
the combined program

Extension Composition

Extension combination refers to the ability to use a number of independent extensions of the same base language in a single program.

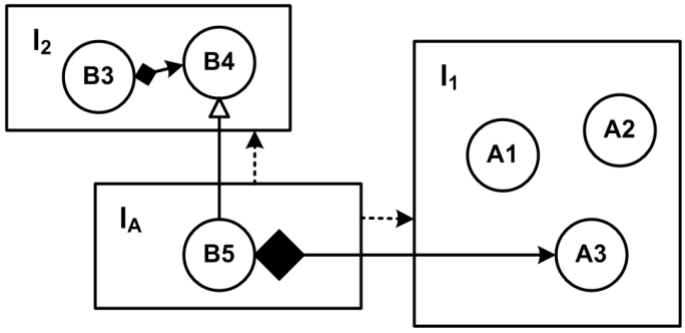
Critically Important!

Language Embedding

Embedding

languages dependencies	homogeneous	heterogeneous
independent	Reuse	Embedding
dependent	Referencing	Extension

fragment structure



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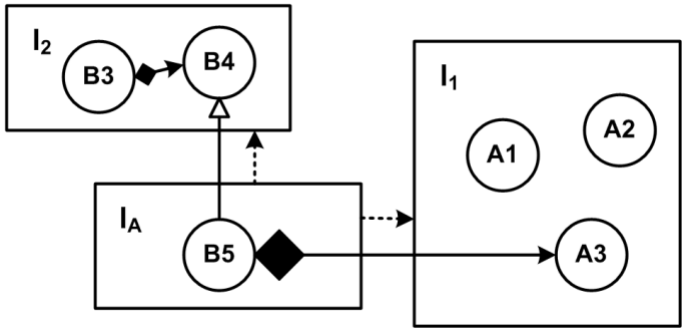

Embedding

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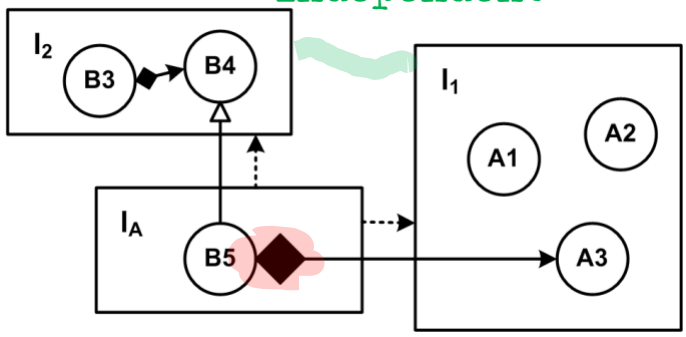
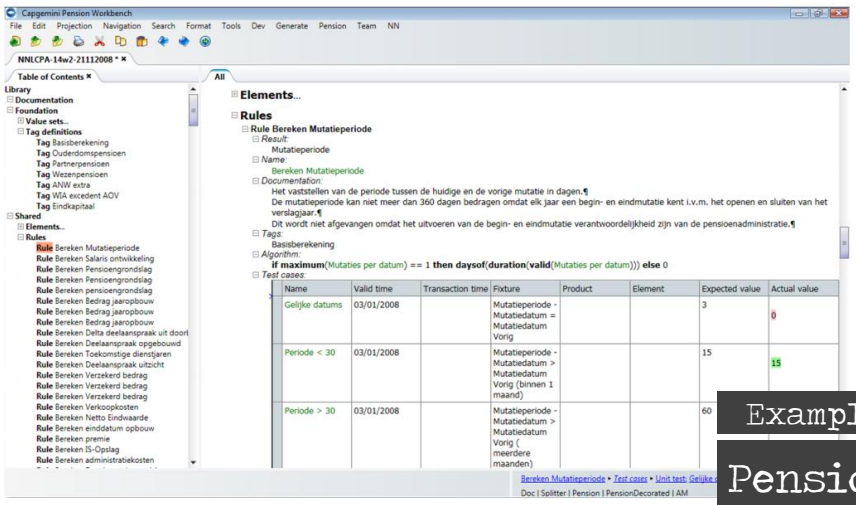
fragment structure

Independent



Containment

Embedding



Example

Pension Plans

Embedding

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

A Systematic Approach

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?

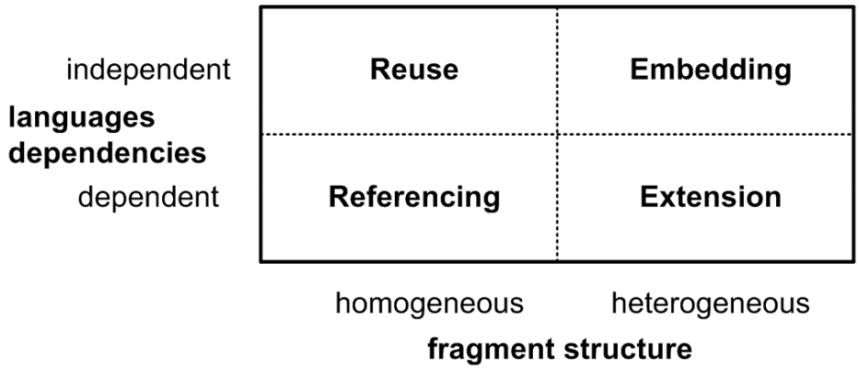
Dependencies:

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

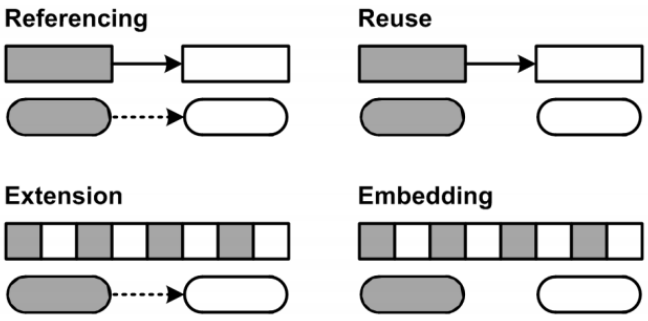
Fragment Structure:

homogeneous vs. heterogeneous („mixing languages")

Dependencies & Fragment Structure:



Dependencies & Fragment Structure:



Concrete Syntax

Combinations

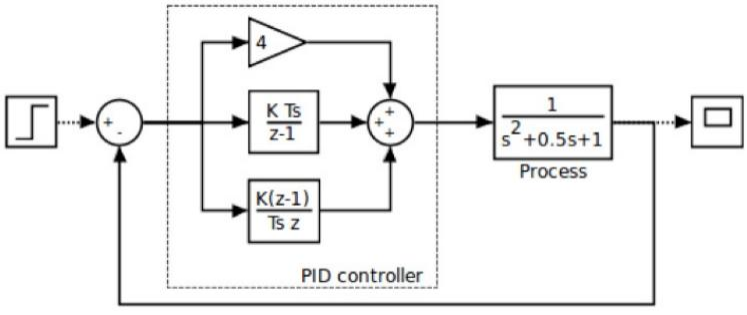
```
c/s interface Decider {
  int decide(int x, int y) pre
}

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

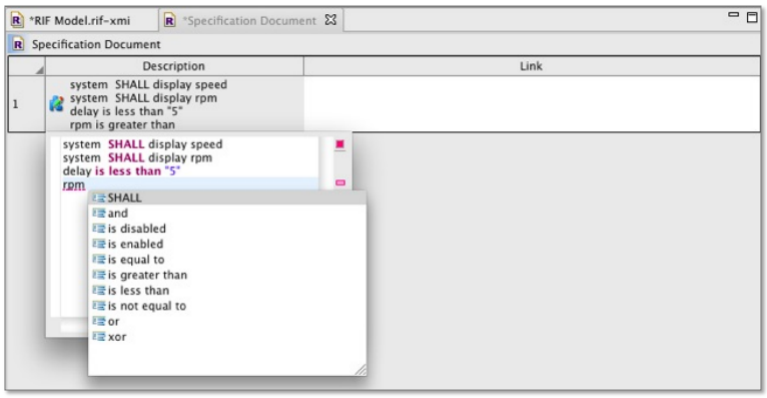
	x == 0	x > 0
y == 0	0	1
y > 0	1	2

```
    ;
    }
}
```

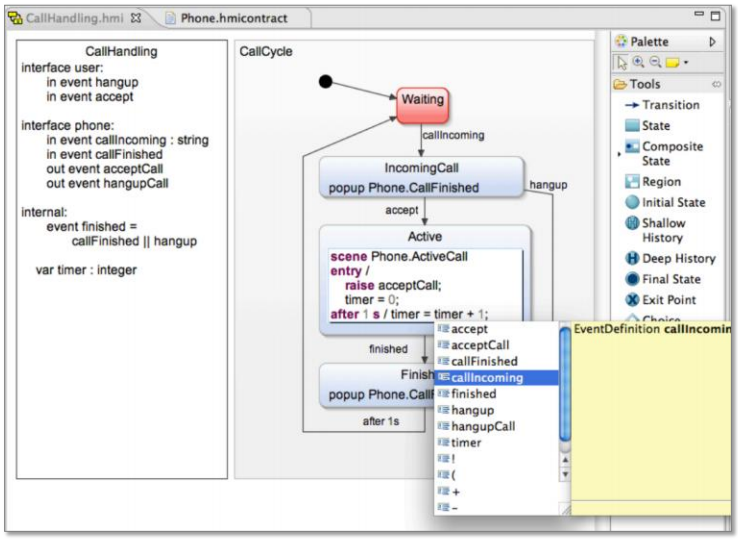
Combinations



Combinations



Combinations



2
Tools

Example Tools

Parser-based LL(k)

eclipse itemis

Example Tools

Projectional

MPS

JetBRAINS

Example Tools

Parser-based GLR

Spoofax

TU Delft

Language Extension

MPS

C extensibility in mbeddr

```
struct Position {
  uint16 x;
  uint16 y;
};

int8 add(int8 x, int8 y) {
  return x + y;
} add (function)

void normalizePosition(Position* p) {
  if (p->x > 100) {
    p->x = 100;
  } if
  if (p->y > 100) {
    p->y = 100;
  } if
} normalizePosition (function)
```

Plain C

Language Extension MPS

C extensibility in mbeddr

```
struct Position {
  uint16 x;
  uint16 y;
};

int8 add(int8 x, int8 y) {
  return x + y;
} add (function)

void normalizePosition(Position* p) {
  if (p->x > 100) {
    p->x = 100;
  } if
  if (p->y > 100) {
    p->y = 100;
  } if
} normalizePosition (function)
```

Plain C

```
exported struct Trackpoint {
  int8 id;
  int8/s/ timestamp;
  int8/m/ x;
  int8/m/ y;
  uint16/m/ alt;
  int16/mps/ speed;
};
```

C + Units

Language Extension MPS

C extensibility in mbeddr

```
requirements modules: FlightJudgementRules
module StateMachines imports DataStructures, stdlib_stub, stdio_stub {

  #define TAKEOFF = 100;
  #define HIGH_SPEED = 10;
  #define VERY_HIGH_SPEED = 20;
  #define LANDING = 100;

  statemachine HierarchicalFlightAnalyzer initial = beforeFlight {
    in next(Trackpoint* tp) <no binding>
    in reset() <no binding>
    out crashNotification() <no binding>
    readable var int16 points = 0
    state beforeFlight {
      on next [tp->alt > 0 m] -> airborne
      exit { points += TAKEOFF; }
    } state beforeFlight
    composite state airborne initial = landed {
      on reset [ ] -> beforeFlight { points = 0; }
      on next [tp->alt == 0 m && tp->speed == 0 mps] -> crashed
      state landed (airborne.landed) {
        entry { points += LANDING; }
      } state landed
    } state airborne
    state crashed {
      entry { send crashNotification(); }
    } state crashed
} }
```

C + State Machines

Language Extension — MPS

C extensibility in mbeddr

```
requirements modules: FlightJudgementRules
module StateMachines imports DataStructures, stdlib_stub, stdio_stub {

  #define TAKEOFF = 100;
  #define HIGH_SPEED = 10;
  #define VERY_HIGH_SPEED = 20;
  #define LANDING = 100;

  statemachine HierarchicalFlightAnalyzer initial = beforeFlight {
    in next(Trackpoint* tp) <no binding>
    in reset() <no binding>
    out crashNotification() <no binding>
    readable var int16 points = 0
    state beforeFlight {
      on next [tp->alt > 0 m] -> airborne
      exit { points += TAKEOFF; }
    } state beforeFlight
    composite state airborne initial = landed {
      on reset [ ] -> beforeFlight { points = 0; }
      on next [tp->alt == 0 m && tp->speed == 0 mps] -> crashed
      state landed (airborne.landed) {
        entry { points += LANDING; }
      } state landed
    } state airborne
    state crashed {
      entry { send crashNotification(); }
    } state crashed
} }
```

C + State Machines

… and Units!

-> combination of independent extensions!

Language Extension — Xtext

„Embedding" Xbase into DSL

```
entity Person {
    lastname : String
    firstname : String
    String fullName(String from) {
        return "Hello " + firstname + " "  + lastname + " from " + from
    }
}
```

Entities using Java types and Xtend code in the body of operations.

Language Extension — Xtext

„Embedding" Xbase into DSL

```
grammar org.xtext.example.lmrc.entityexpr.EntityWithExprDsl
        with org.eclipse.xtext.xbase.Xbase

generate entityWithExprDsl
           "http://www.xtext.org/example/lmrc/entityexpr/EntityWithExprDsl"

Module:
    "module" name=ID "{"
        entities+=Entity*
    "}";
```

```
Attribute:
    name=ID ":" type=JvmTypeReference;

Operation:
    type=JvmTypeReference name=ID "("  (parameters+=FullJvmFormalParameter
        (',' parameters+=FullJvmFormalParameter)*)? ")"
            body=XBlockExpression;
```

Language Extension — Xtext

„Embedding" Xbase into DSL

```
class EntityWithExprDslJvmModelInferrer extends AbstractModelInferrer {

    @Inject extension IQualifiedNameProvider
    @Inject extension JvmTypesBuilder

    def dispatch void infer(Entity entity,
                            IAcceptor<JvmDeclaredType> acceptor,
                            boolean isPrelinkingPhase) {
        ...
    }
}
```

See before … results in generator, scoping, typing, etc. with little additional work.

Language Extension — Xtext

Extending Xbase with Dates

Grammar

```
XDateLiteral:
    'date' ':' year=INT '-' month=INT '-' day=INT;
```

```
XLiteral returns xbase::XExpression:
    XClosure |
    XBooleanLiteral |
    XIntLiteral |
    XNullLiteral |
    XStringLiteral |
    XTypeLiteral |
    XDateLiteral;
```

Repeat complete Xliteral rule,
adding the XDateLiteral

Language Extension — Xtext

Extending Xbase with Dates

Type system

```
@Singleton
public class DomainModelTypeProvider extends XbaseTypeProvider {

    @Override
  protected JvmTypeReference type(XExpression expression,
                  JvmTypeReference rawExpectation, boolean rawType) {
    if (expression instanceof XDateLiteral) {
      return _type((XDateLiteral) expression, rawExpectation, rawType);
    }
    return super.type(expression, rawExpectation, rawType);
  }

  protected JvmTypeReference _type(XDateLiteral literal,
              JvmTypeReference rawExpectation, boolean rawType) {
    return getTypeReferences().getTypeForName(Date.class, literal);
  }
}
```

Language Extension

Xtext

Extending Xbase with Dates

Interpreter

```
public class DateExtensions {
    public static long operator_minus(Date a, Date b) {
        long resInMilliSeconds = a.getTime() - b.getTime();
        return millisecondsToDays( resInMilliSeconds );
    }
}
```

Compiler

```
public class DomainModelCompiler extends XbaseCompiler {
  protected void _toJavaExpression(XDateLiteral expr, IAppendable b) {
    b.append("new java.text.SimpleDateFormat(\"yyyy-MM-dd\").parse(\"" +
             expr.getYear() + "-" + expr.getMonth() + "-" +
             expr.getDay() + "\")");
  }
}
```

Embedding

MPS

Useful for Meta Data

```
requirements modules: FlightJudgementRules
module StateMachines imports DataStructures, stdlib_stub, stdio_stub {

  [#define TAKEOFF = 100;] -> implements PointsForTakeoff
  [#define HIGH_SPEED = 10;] -> implements FasterThan100
  [#define VERY_HIGH_SPEED = 20;] -> implements FasterThan200
  [#define LANDING = 100;] -> implements FullStop

  statemachine FlightAnalyzer initial = beforeFlight {
    in next(Trackpoint* tp) <no binding>
    in reset() <no binding>
    out crashNotification() ⊠ raiseAlarm
    readable var int16 points = 0
    state beforeFlight {
      entry { points = 0; } entry
      on next [tp->alt > 0 m] ⊠ airborne
      [exit { points += TAKEOFF; } exit] -> implements PointsForTakeoff
    } state beforeFlight
    state airborne {
      on next [tp->alt == 0 m && tp->speed == 0 mps] ⊠ crashed
      on next [tp->alt == 0 m && tp->speed > 0 mps] ⊠ landing
      [on next [tp->speed > 200 mps] ⊠ airborne { points += VERY_HIGH_SPEED; } on next] -> implements FasterThan200
      [on next [tp->speed > 100 mps] ⊠ airborne { points += HIGH_SPEED; } on next] -> implements FasterThan100
      on reset [ ] ⊠ beforeFlight
    } state airborne
    state landing {
      on next [tp->speed == 0 mps] ⊠ landed
      [on next [ ] ⊠ landing { points--; } on next] -> implements ShortLandingRoll
      on reset [ ] ⊠ beforeFlight
    } state landing
```

No Dependencies on anything.

Extending the Tool

MPS

… since it is bootstrapped!

```
public boolean isLinear(node<Expression> expr) {
  return dispatch<boolean> (expr) {
    NumberLiteral        ⇒ true
    EnumLiteralRef       ⇒ true
    LiteralWithUnit      ⇒ #(it.value)
    BinaryComparisonExpr ⇒ #(it.left) && #(it.right)
    BinaryLogicalExpress ⇒ #(it.left) && #(it.right)
    PlusExpression       ⇒ #(it.left) && #(it.right)
    LocalVarRef          ⇒ true
    ArgumentRef          ⇒ true
    MemberRef            ⇒ true
    SUArrowExpression    ⇒ #(it.member)
    SUDotExpression      ⇒ #(it.member)
    NotExpression        ⇒ #(it.expression)
    GlobalVarRef         ⇒ true
    MultiExpression      ⇒ it.left.isStaticallyEvaluatable() || it.right.isStaticallyEvaluatable()
    DivExpression        ⇒ it.left.isStaticallyEvaluatable() || it.right.isStaticallyEvaluatable()
    default false
  };
}
```

Extending the Tool

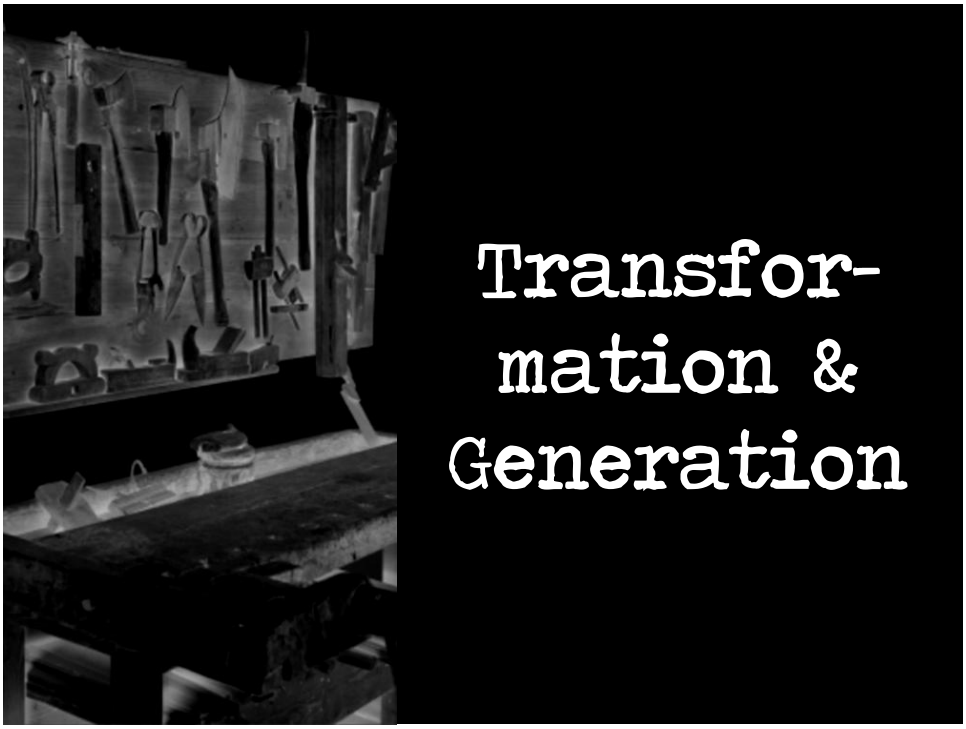
MPS

… since it is bootstrapped!

```
test TestGuard2 {
  node<PlusExpression> plus = <4 + 2 / 3>;
  node<Expression> cand = plus.rightExpression : DivExpression.rightExpression;
  boolean matched = false;
  when matched cand against [t /IntegerConstant #t.value == 3;
                             p /DivExpression;
                             a /PlusExpression #a.leftExpression.isInstanceOf(IntegerConstant) ==plus;] {
    matched = true;
  }
  assert true matched;
}
```

```
node<GlobalVariableDeclaration> gvd = build GlobalVariableDeclaration
  name = name
  type = #(type)
  preventNameMangling = true
  extern = isExtern
;
```

Extending MPS is (almost) like extending any other language!



Multi-Stage Trafo

MPS

MPS' Transformations

```
module Statemachine imports nothing {

  statemachine Counter {
    in events
      start()
      step(int[0..10] size)
    out events
      started()
      resetted()
      incremented(int[0..10] newVal)
    local variables
      int[0..10] currentVal = 0
      int[0..10] LIMIT = 10
    states ( initial = start )
      state start {
        on start [ ] -> countState { send started(); }
      }
      state countState {
        on step [currentVal + size > LIMIT] -> start { send resetted(); }
        on step [currentVal + size <= LIMIT] -> countState {
          currentVal = currentVal + size;
          send incremented(currentVal);
        }
        on start [ ] -> start { send resetted(); }
      }
  }

  Counter c1;
  Counter c2;

  void aFunction() {
    trigger(c1, start);
  }
}
```

Multi-Stage Trafo

MPS

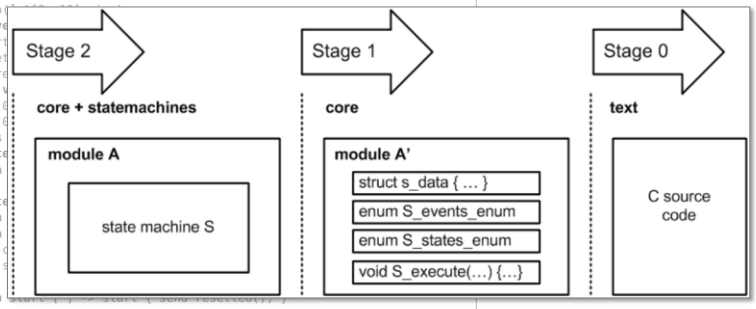
MPS' Transformations

```
module Statemachine imports nothing {

  statemachine Counter {
    in events
      start()
      step(
    out eve
      start
      reset
      incr
    local
      int[
      int[
    states
      state
        on
      }
      state
        on
        on
      }
      on
    }
  }

  Counter c1;
  Counter c2;

  void aFunction() {
    trigger(c1, start);
  }
}
```



Transformations

MPS

with concrete Syntax & IDE

```
template weave_StatemachineTypesStuffIntoModule
input    Statemachine
content node:
module dummy imports nothing {
  <TF [ exported enum $[statemachineInEvents] { $LOOP$[$[anEvent]; ] } ] TF>
  <TF [ exported enum $[statemachineStates] { $LOOP$[$[aState]; ] } ] TF>
  <TF [ exported struct $[statemachineData] {                       ] TF>
        [   ->$[statemachineStates] __currentState;                 ]
        [   $LOOP$[$COPY_SRC$[int8_t] $[smLocalVar]; ]              ]
        [ };                                                        ]
}
```

IDE support for target language
Macros contain template code
M2M with M2T „feel"

Transformations MPS

with concrete Syntax & IDE

```
template weave_StatemachineTypesStuffIntoModule
input    Statemachine
content node:
module dummy imports nothing {
  <TF [ exported enum $[statemachineInEvents] { $LOOP$[$[anEvent]; ] } ] TF>
  <TF [ exported enum $[statemachineStates] { $LOOP$[$[aState]; ] } ] TF>
  <TF [ exported struct $[statemachineData] {                       ] TF>
        [   ->$[statemachineStates] __currentState;                 ]
        [  $LOOP$[$COPY_SRC$[int8_t] $[smLocalVar]; ]               ]
      [ };                                                          ]
}
```

```
comment       : <none>
mapping label : <no label>
mapped nodes  : (node, genContext, operationContext)->sequence<node<>> {
                  node.states;
                }
```

Transformations MPS

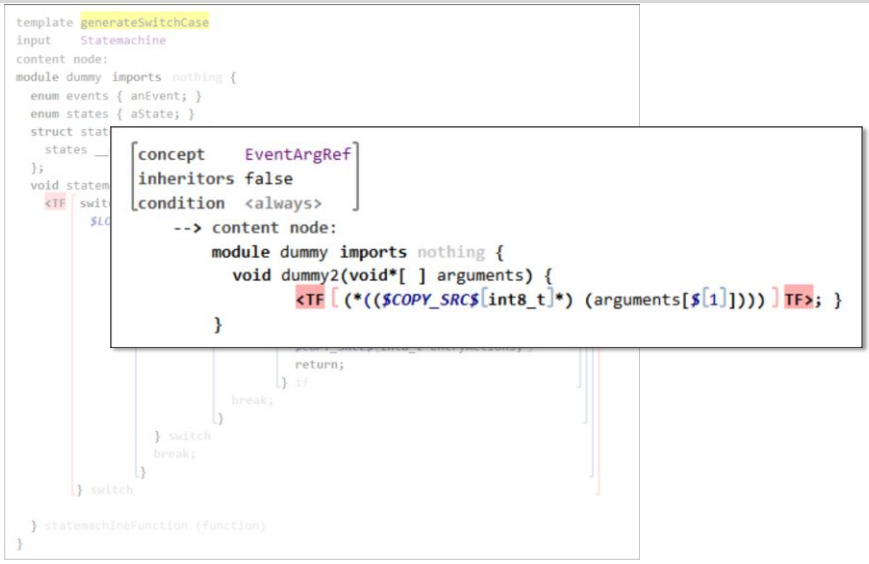
with concrete Syntax & IDE

```
template generateSwitchCase
input    Statemachine
content node:
module dummy imports nothing {
  enum events { anEvent; }
  enum states { aState; }
  struct statemachineData {
    states __currentState;
  };
  void statemachineFunction(statemachineData* instance, events event) {
    <TF [ switch ( instance->__currentState ) {                                  ] TF>
        [  $LOOP$[case ->$[aState]: {                                            ]
        [          switch ( event ) {                                            ]
        [            $LOOP$[case ->$[anEvent]: {                                 ]
        [                     $LOOP$[if ( $COPY_SRC$[true] ) {                   ]
        [                              $COPY_SRC$[int8_t exitActions;]           ]
        [                              $COPY_SRC$[int8_t transActions;]          ]
        [                              instance->__currentState = ->$[aState];   ]
        [                              $COPY_SRC$[int8_t entryActions;]          ]
        [                              return;                                   ]
        [                     } if                                               ]
        [                   break;                                               ]
        [            }                                                           ]
        [          } switch                                                      ]
        [          break;                                                        ]
        [  }                                                                     ]
      [ } switch                                                                 ]

  } statemachineFunction (function)
}
```

Transformations MPS

with concrete Syntax & IDE



Transformations MPS

With local dependencies

A transformation only specifies its relative priority to other transformations as necessary.

This leads to composability also of transformations.

IDE
Services

Find References — MPS

Custom Finders

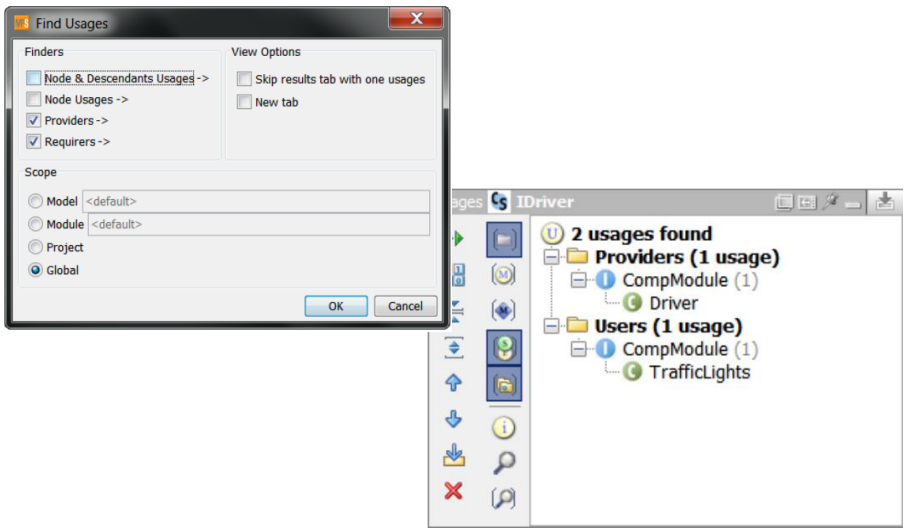
```
finder findProviders for concept Interface
  description: Providers

  find(node, scope)->void {
    nlist<> refs = execute NodeUsages ( node , <same scope> );
    foreach r in refs.select(it|it.isInstanceOf(ProvidedPort)) {
      add result r.parent ;
    }
  }

  getCategory(node)->string {
    "Providers";
  }
```

Find References — MPS

Custom Finders



Testing

Parser/Syntax Testing — Spoofax

Declarative Approach

abstract syntax

```
test multiply and add [[1 + 2 * 3]] parse to Add(_, Mul(_, _))
test add and multiply [[1 * 2 + 3]] parse to Add(Mul(_, _), _)
test add and add [[1 + 2 + 3]] parse to Add(Add(_, _), _)
```

concrete syntax

```
test multiply and add [[1 + 2 * 3]] parse to [[1 + (2 * 3)]]
test add and multiply [[1 * 2 + 3]] parse to [[(1 * 2) + 3]]
test add and add [[1 + 2 + 3]] parse to [[(1 + 2) + 3]]
```

Constraints/Type Sys. — MPS

Declarative Approach

```
Test case testSubtyping
nodes
  ( [ <check types module TestSubtyping imports nothing { >
                  <dnode  double d = 10;>
                  double d2 = <dref  d>;
                  double d3 = <node d has type double>;
                  int8 i = <node d has error>;
                }                                          ] )

test methods
  test testReference {
    assert dref.var == dnode;
  }
```

Test annotations on the test subject - very concise.

Testing Semantics

MPS

Expressing tests in language

```
module UnitTestDemo {

  int32 main(int32 argc, int8*[ ] argv) {
    return test testMultiply;
  }

  test case testMultiply {
    assert (0) times2(21) == 42;
    assert (1) times2(0) == 0;
    assert (2) times2(-10) == -20;
  }

  int8 times2(int8 a) {
    return 2 * a;
  }
}
```

Generate/Interpret the tests along with the application code

Testing Editors

Xtext

Using Moritz Eysholdt's Xpect

```
// XPECT_TEST org.example.MyJUnitContentAssistTest END_TEST

// XPECT contentAssist at |Hel --> Hello
Hello Peter!

// XPECT contentAssist at |! --> !
Hello Heiko!
```

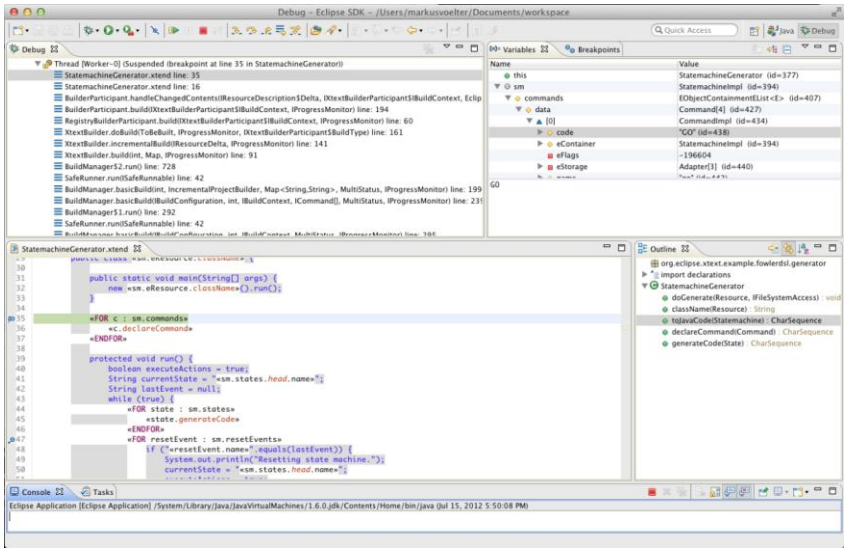
Test expectations in comments.

Can test various language aspects such as scopes, code completion, type system; also extensible.

Inspecting/ Debugging

Debugging DSLs — Xtext

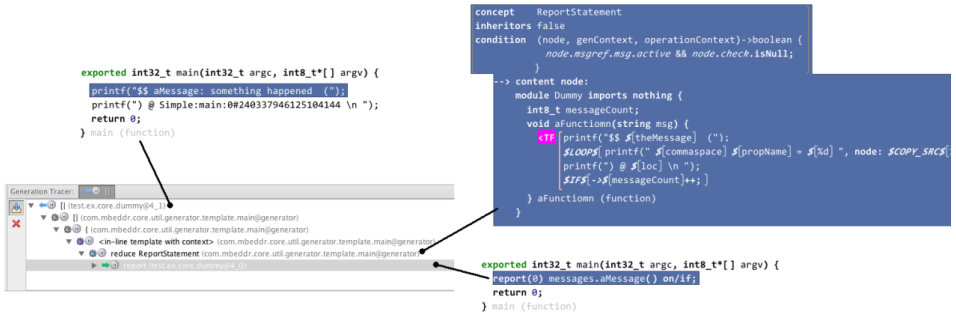
Transformations & Code Gens



Debugging DSLs — MPS

Transformations

Multi-Level, Declarative:
show intermediate models and the templates involved in trafo.



Debugging DSL Programs Xtext

Xbase Automatic Debugging

Make your DSL extend Xbase
Use a JVMModelInferrer → Java
you then get Debugging for free

Debugging DSL Programs MPS

Extensible Debuggers

```
int8 s = 0;
int8[] a = {1, 2, 3};
foreach (a sized 3) {
    s += it;
}
```

Debugging DSL Programs MPS

Extensible Debuggers

```
int8 s = 0;
int8[] a = {1, 2, 3};
foreach (a sized 3) {
    s += it;
}
```

Language Extension

```
int8 s = 0;
int8[] a = {1, 2, 3};
for (int __c = 0; __c < 3; __c++) {
    int8 __it = a[__c];
    s += __it;
}
```

Generated C Code

Debugging DSL Programs MPS

Extensible Debuggers

```
int8 s = 0;
int8[] a = {1, 2, 3};
foreach (a sized 3) {
    s += it;
}
```

Stepping

```
void contributeStepOverStrategies(list<IDebugStrategy> res) {
   ancestor
   statement list: this.body
}
```

```
void contributeStepIntoStrategies(list<IDebugStrategy> res) {
  subtree: this.array
  subtree: this.len
}
```

Debugging DSL Programs MPS

Extensible Debuggers

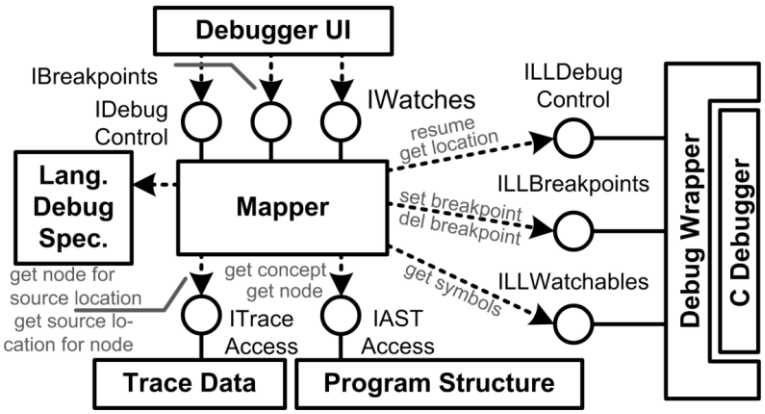
```
int8 s = 0;
int8[] a = {1, 2, 3};
foreach (a sized 3) {
    s += it;
}
```

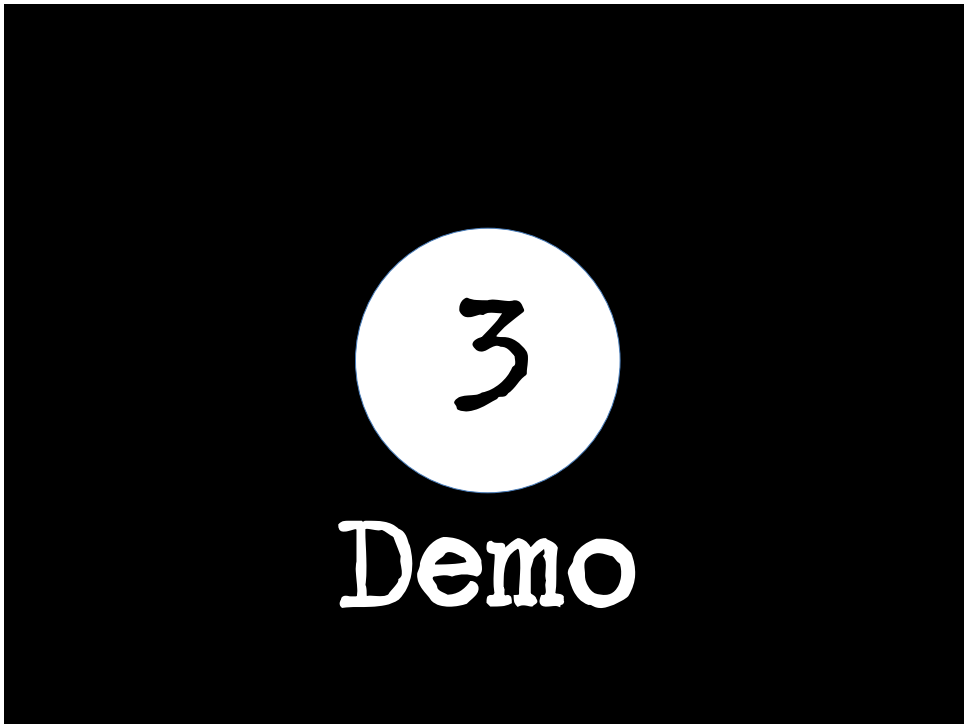
Watches

```
void contributeWatchables(list<UnmappedVariable> unmapped,
                          list<IWatchable> mapped) {
  hide "__c"
  map "__it" to "it"
    type: this.array.type : ArrayType.baseType
    category: WatchableCategories.LOCAL_VARIABLES
    context: this
}
```

Debugging DSL Programs MPS

Debugger Architecture




3
Demo

mbeddr
C the Difference. C the Future.

An extensible Version of C (and an IDE and a Debugger)

Bundesministerium für Bildung und Forschung

gefördert durch das BMBF
Förderkennzeichen 01IS11014

The End.

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