Early Experience with Language Interoperability

Porting the BETA language to Java and .NET

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- Virtual machines
  - The Java- and .NET platforms
- BETA
- Mapping BETA to Java and .NET
- Experience with the platforms
- Language interoperability
- Demo
- Conclusion

Background

- Modern language implementations:
  - Virtual machines
  - Bytecode
  - Just-in-time compilers
  - Run-time type information
  - Verification of code before execution
- Main stream platforms
  - Java virtual machines
  - Microsoft .NET

Main stream OO languages

- Java
  - The one and only language for the Java-platform
- C# and VB.Net
  - The dominant languages for .NET
- A family of languages
  - Java/C#-like languages
  - And many more

Goals I

- Implement BETA for
  - .NET
  - Java-VM
- Investigate the suitability of Java and .NET as platforms for general language implementation

Goals II

- Investigate language interoperability
- Traditional language interoperability for procedural languages
  - Procedure libraries in different languages
  - Common calling sequence for procedures
- Language interoperability for OO languages
  - Uses of classes from different languages
  - Inheritance from classes in different languages
  - An explicit goal for .NET
  - No expectations for Java

Goals III

- Provide a common language for .NET and Java-VM
- (Component architecture)
  - Web services – SOAP
- (BETA for PDA’s)
  - .NET compact framework

Challenges I

Mapping of BETA to .NET & Java-VM

- .NET & Java-VM are typed virtual machines modelled from Java and C#
- BETA is much more general
- One issue: just finding a mapping

Challenges II

Language interoperability

- BETA should be able to uses classes from other languages
- Other languages should be able to use BETA classes (patterns)
- BETA should be able to inherit classes from other languages
- Other languages should be able to inherit from BETA
- The BETA mapping should be ’nice’ when seen from other languages

Java/C# language model

- A program is a collection of classes
- A class defines
  - Data-items/attributes
    - an attribute has a type
  - Methods
    - a method has arguments and a possible result value
- Classes may be nested
  - Java – real nesting
  - C# - only a scope mechanism
- No nesting of methods
- Dynamic exceptions
- Concurrency in the form of threads

BETA

- Class and method unified into the pattern mechanism
- General nesting of patterns
- INNER instead of super
- Genericity in the form of virtual patterns
- Multiple return values
- Active objects
  - Coroutines and concurrency
  - Basis for writing schedulers
- No constructors
- No dynamic exceptions (yet)

Challenges with BETA mapping

- Pattern mapping to class and methods
- Nested patterns
- Nested procedures
- Enter-do –exit-semantics
- Inner
- Virtual patterns – class and procedure
- Multiple return values
- Leave/restart out of nested method activations
- Coroutines and concurrency
- Pattern variables
- Basic values – signed/unsigned

The mapping

- Generating code for Java- and .NET corresponds to making a BETA source mapping into Java- and/or C#-source code
- In the following the implementation of BETA is shown as a mapping into a Java/C#-like language

BETA example

```
Calc:
 (# R: @integer;
    set:
     (# V: @integer enter V do V → R #);
    add:
     (# V: @integer enter V do R+V → R exit R #);
 #);

C: @Calc; X: @integer;
12 → C.set;
5 → C.add → X
```

Naive mapping into Java/C#

```
Class Calc extends Object
{ int R;
  void set(int V) { R = V; };
  int add(int V)
   { R = R + V; return R;}
}

Calc C = new Calc(); int X;
C.set(12);
X = C.add(5);
```

Instances of add

- More complex mapping needed
- Possible to create instances of pattern add

```
C: @Calc; X: @integer;
A: ^C.add;

&C.add[] → A[];
6 → A → X
```

Creation of an instance of C.add

Class add

```
class add extends Object
{ Calc origin ;
  int V;
  void add(Calc org) {origin = org; }
  void enter(int a) { V = a; }
  void do() { origin.R = origin.R + V };
  int exit() { return origin.R; }
}
```

```
C: @Calc;
X: @integer;
12 → C.set;
5 → C.add → X
```

```
add A; int X;
A = new add(C);
A.enter(5);
A.do()
X = A.exit();
```

Calc with call-add operation

```
Class Calc extends Object
{ int R;
  void set(int V) { R = V; };
  int add(int V)
   { add A;
     A = new add(this);
     A.enter(V);
     A.do()
     return A.exit();
   }
}
```

```
Calc C = new Calc(); int X;
C.set(12);
X = C.add(5);
```

We hope the JIT compilers inlines these calls!

Calc with call-add & new-add

```
Class Calc extends Object
{ int R;
  void set(int V) { R = V; };

  int add(int V) { ...; return A.exit(); }

  add add () { return new add(this); }
 }
```

Call method for add

New method for add

```
Calc C = new Calc(); int X; add C.A;
C.set(12);
X = C.add(5);
A = C.add();
```

General scheme

```
myClass:
 (# ...;
    f1: (# ... #);
    f2: (# ... #);
    f3: (# ... #)
 #)
```

```
class myClass extends Object
 { ...;
   T1 f1(...) { ... } // call f1
   f1 f1() { ... }    // new f1
   T2 f2(...) { ... } // call f2
   f2 f2() { ... }    // new f2
   T3 f3(...) { ... } // call f3
   f3 f3() { ... }    // new f3
}
```

With language restrictions

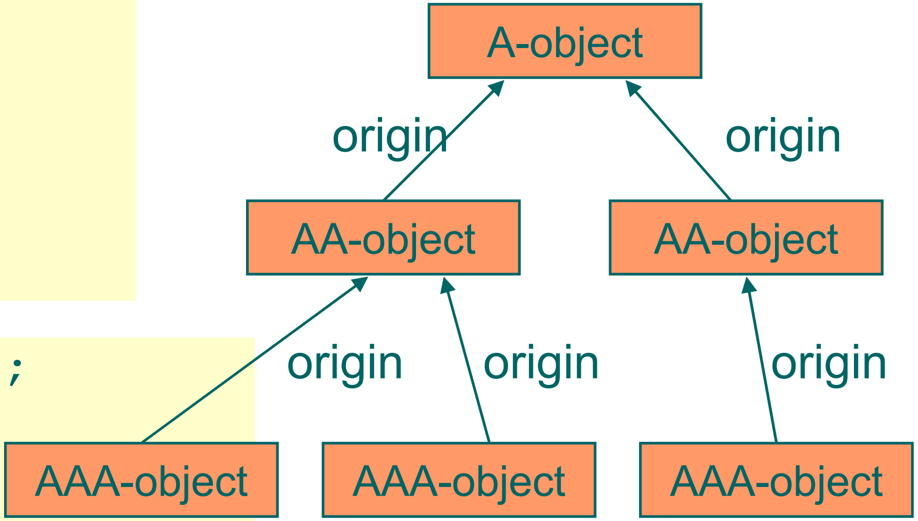
```
myClass: class
 (# ...;
    f1: proc(# ... #);
    f2: proc(# ... #);
    T: class(# ... #)
  #)
```

```
class myClass extends Object
 { ...;
   T1 f1(...) { ... } // call f1
   T2 f2(...) { ... } // call f2
   T T() { ... }      // new T
 }
```

Nested/inner classes in general

```
A: (# ...
      AA: (# ...
             AAA: (# ... #)
           #)
   #)
```

```
class A extends Object { ... };
class AA extends Object
 { A origin,
   void AA(A org) { origin = org; }
 }
class AAA extends Object
 { AA origin;
   void AAA(AA org) { origin = org; }
 }
```



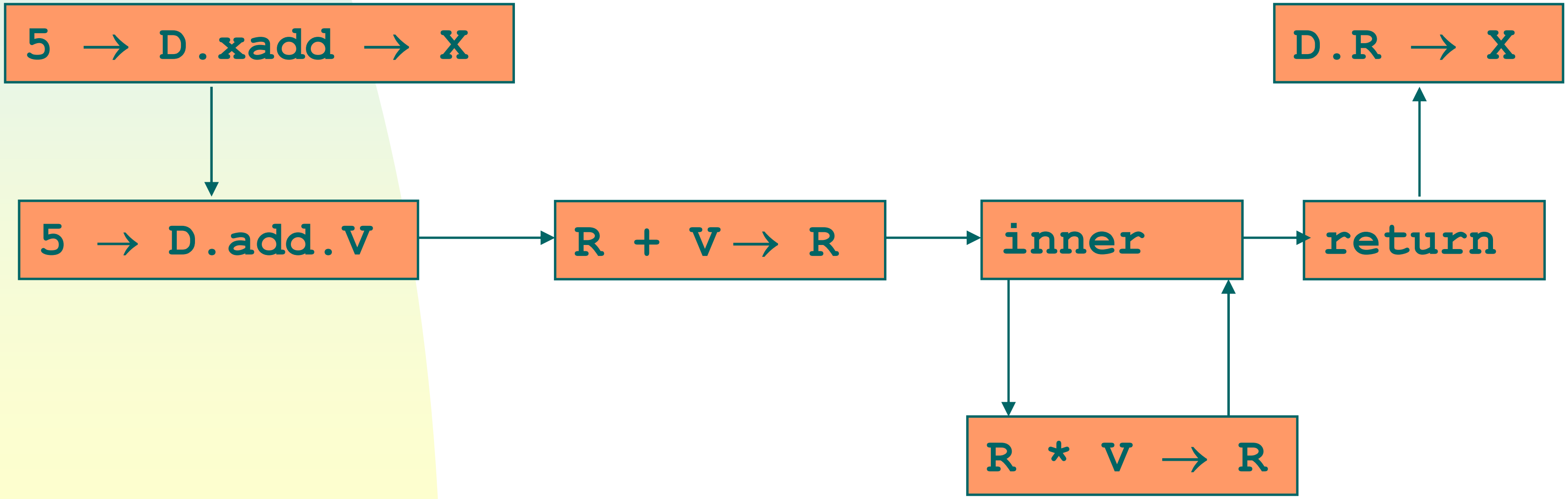
Method combination with inner

```
Calc:
  (# ...
     add:
      (# V: @integer
      enter V
      do R+V → R; inner
      exit R
      #);
     ...
   #)
Xcalc: Calc
 (#
    xadd: add (# do R * V → R #)
 #)
```

Semantics of inner

```
D: @Xcalc; X: @integer
12 → D.set;
5 → D.xadd → X
```

```
add:  (# V: @integer
        enter V
        do R+V → R; inner
        exit R
        #);
xadd: add (# do R * V → R #)
```



5 → D.xadd → X

5 → D.add.V

R + V → R

inner

R * V → R

return

D.R → X

Class add with inner

```
class add extends Object
{ ...
  void do()
   { origin.R = origin.R + V;
     do_1(); // inner
   };
  void do_1();
}
```

```
class xadd extends add
{ ...
  void do_1()
   { origin.R = origin.R * V;
   };
  ...
}
```

Inner at several levels

```
A: (# do X1; inner; Y1 #);
AA: A (# do X2; inner; Y2 #);
AAA: AA(# do X3; inner; Y3 #)
```

```
class A: extends Object
  { void do() { X1; do_1(); Y1; };
    void do_1()
  }
class AA: extends A
  { void do_1() { X2; do_2(); Y2; };
    void do_2()
  }
class AAA: b AA
  { void do_2() { X3; do_3(); Y3 };
    void do_3()
  }
```

Virtual patterns

- BETA has virtual patterns
- Virtual patterns used as virtual procedures
  - Like virtual methods in Java/C#
- Virtual patterns used as virtual classes
  - A mechanism for defining a class parameterized by another class
- No counter parts in Java/C#
  - Proposal on its way for Java

Pattern List

```
List:
  (# element:< Object;
     insert:
       (# e: ^element
        enter e[] do ... #);
     ...
   #)
StudentList: List
   (# element::< Student;
   #)
```

```
L: @List;
aPerson[] → L.insert;
aStudent[] → L.insert;
```

```
S: @StudentList;
aPerson[] → S.insert;
aStudent[] → S.insert;
```

Illegal

Detected by the BETA compiler

Virtual class in Java/C#

```
class List extends Object
 { ...
   void insert(Object e) { ... }
 }
```

```
class StudentList extends List
 { ...
   void insert(Object e)
    { Student e1 = (Student) e;
       ...
    }
 }
```

Multiple return values

```
Calc:
 (# R,Rx: @integer;
    ...;
    getReg: (# exit(R,Rx) #);
 #);

C: @Calc; x,y: @integer;
C.getReg → (x,y);
```

- A field is added to the class for each return value
- At the calling site, the exit fields are fetched

Leave/restart of nested method calls

```
foo:
 (#
 do L: (# bar: (# do leave L #);
          go: (# do restart L #)
       do (if b then
              bar
          else
              go
          if)
       #)
 #);
```

To be implemented using dynamic exceptions

Remaining issues

- Active objects
  - Coroutines and concurrency
- Pattern variables
  - Classes and methods as first-class values
- Basic values – signed/unsigned
- And lots of details

Compiler organization

- Frontend
  - Parser,
    abstract syntax trees,
    semantic checking,
    semantic analysis,
    abstract code generation
  - Platform independent
- Backend
  - Code generation for a specific target
  - Platform dependent
    - Sun Solaris
    - Linux
    - Windows
    - Macintosh

Compiler reorganization

- Frontend
  - Generate (typed) stack code
- Backend
  - Abstract stack code
  - Specific targets
    - .NET
    - Java-VM

Platform issues I

- No static link on stack frames
  - Nested procedures/methods cannot be implemented using the stack
- Very rigid typing of class-fields
  - And method-locals on .NET
- Constructor initialization
  - Impossible to make setups before calling super constructor
- General exit out of nested method calls
- No support for covariant arguments
- No support for covariant return types
- Active objects

Platform issues II

- .NET class references must be fully qualified, including location of binding
  - Problems with separate compilation
- Large number of classes generated due to the generality of BETA patterns
  - Java class files can only contain one (non-static) class per file
  - Lots of class files are generated
- .NET assemblies can contain any number of classes

Platform issues III (minor)

- No swap and dup_x1/x2 on .NET
- Requirements for fully typed local variables in .NET.
    - Means that swap cannot be implemented in backend using local variables unless type of two top-of-stack objects are known.
- Type of field: super/this class

Platform advantages

- Well-defined run-time format
  - More than just a calling convention for procedures
- Memory management
  - Storage allocation
  - Object format & method activation format
  - Garbage collection
- Efficient code generation
- We will have BETA for all Java- and .NET platforms
- Can this be utilized efficiently?
  - If simple and direct mapping – yes
  - If complex mapping – no?
  - Inlining may help
    - ☞ Can rely on generating methods that the JIT inlines

Language interoperability I

- Java/C# class inherited from BETA
  - Straight forward
  - Since name & type-based,
    - just specify the methods you will use
  - Simpler than for COM
    - COM uses offsets
    - All preceding methods must be declared
- BETA pattern inherited from Java/C# class
  - Also straight forward
  - Issues with default constructor
    - BETA object requires surrounding object (origin)

Language interoperability II

- Issues
  - Libraries and frameworks in Java/C#
  - Java-string, C#-String, BETA-text
    - Automatic coercion implemented
  - Overloading
  - Constructors
- External class interface
  - Interface syntax needed – currently clumsy
  - External name & location
  - Automatic include of interface files
    - .NET assemblies
    - Java class-files

Demo

- Inheritance in BETA of external class
  - Java Applet
- Inheritance of BETA pattern in Java and C#
- Implementation of program using Google web-service
  - In C# and Java
- Debugging of Google search in Visual Studio.Net

Conclusion

- Not trivial to map all parts of BETA
- We still need to measure efficiency
- Generation of bytecode: straightforward
  - Java issue: no standard assembler
- Generation of type information: a lot of work
- No real problems in supporting both platforms
- Use of Visual Studio to edit and debug BETA programs
  - Impressive
  - Source level debugging, breakpoints, object-inspection, ...

Language interoperability

- .NET/C#: seems to work as promised
  - Class instance
  - Inheritance
  - Visual Studio
- Java: works well too – to our surprise
  - Class instance
  - Inheritance
  - Has not found any (free) SDE’s that work as well as Visual Studio (which is expensive, but stand alone graphical debugger part of free .NET framework)
- It seems realistic to mix libraries and frameworks from different languages
- Easier to introduce new languages

BETA Language changes

- Constructors
- Restricting a pattern as class or method
- Add properties as in C#
- Issue with super/inner call sequencing
- Overloading?

Status

- Large subset of BETA has been implemented
- To be done
  - General leave/restart
  - Active objects
  - Pattern variables
  - Lots of details
  - Porting BETA libraries and frameworks to Java and .NET

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