Integrating Coercion with Subtyping and Multiple Dispatch

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(joint work with Joe Hallett, Sukyoung Ryu, Guy Steele)

```
4*pi*r**3/3
```

```
4*pi*r**3/3
```

```
REAL(4)*pi*REAL(r**3)/REAL(3)
```

```
class Node {
   Object item;
   ...
   Node(Object x) { item = x; }
   ...
}
Node n = new Node(3);
```

```
class Node {
   Object item;
   ...
   Node(Object x) { item = x; }
   ...
}
Node n = new Node(3);


Node n = new Node(Integer(3));
```

Coercion reduces clutter

```
Sub printStr(s As String, n As Integer)
  For i As Integer = 1 to n
    Console.Write(s)
  Next i
End Sub
```

Adapted from Peterson

- What does `printStr(7, "4")` do?

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Writes `"7"` 4 times to `Console`.

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  For i As Integer = 1 to n
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  Next i
End Sub
```

- What does `printStr(7, "4")` do?

Writes `"7"` 4 times to `Console`.

```
dcl A fixed bin(15,10);
A = 1.23;

dcl B fixed dec(4,3);
B = 1.230 - A;
```

```
dcl A fixed bin(15,10);
A = 1.23;

dcl B fixed dec(4,3);
B = 1.230 - A;
```

B is 0.003!

```
4/3*pi*r**3
```

- Does this compute the volume?

```
4/3*pi*r**3
```

- Does this compute the volume?

```
4.0/3.0*pi*r**3
```

/ is overloaded.

```
4*pi*r**3/3
```

```
REAL(4)*pi*REAL(r**3)/REAL(3)
```

Why not coerce this?

```
double f(float a, double b) {
  return a*a + b;
}
```

```
double f(float a, double b) {
  return (double)a*(double)a + b;
}
```

Why coerce this?

```
Sub addStrings(a As String, b As String)
  Console.Write(a+b+1)
  Console.Write(1+a+b)
End Sub
```

- What does `addStrings(3, 20)` do?

```
Sub addStrings(a As String, b As String)
   Console.Write(a+b+1)
   Console.Write(1+a+b)
End Sub
```

- What does `addStrings(3, 20)` do?

Writes: `321`
`24`

```
public class Test {
   static void main(String[] args) {
      System.out.println(3+20+1);
      System.out.println(1+3+20);
      System.out.println(1+3+"20");
      System.out.println(1+"3"+20);
   }
}
```

Writes:

```
24
24
420
1320
```

```
public class Test {
   static void main(String[] args) {
      int five = 5;
      Number n = five;
   }
}
```

coerced to `Integer`, which extends `Number`

```
class Int {
  implicit operator Int(int i) {...}
}
class Test {
  static void test(Int z) {
    Console.WriteLine("Int");
  }
  static void test(long l) {
    Console.WriteLine("long");
  }
  static void Main() {
    int i = 5;
    test(i);
  }
}
```

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```

should be `public static implicit ...`

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  }
}
```

`int` coerces to `Int`

`int` coerces to `long`

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class Int {
  implicit operator Int(int i) {...}
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class Test {
  static void test(Int z) {
    Console.WriteLine("Int");
  }
  static void test(long l) {
    Console.WriteLine("long");
  }
  static void Main() {
    int i = 5;
    test(i);
  }
}
```

int coerces to Int

int coerces to long

error: ambiguous call

```
class List {...}
class OList : List {
  implicit operator BinTree(OList l) {...}
}
class BinTree {
  implicit operator List(BinTree t) {...}
}
class Test {
  static void print(BinTree t) {
    Console.WriteLine("BinTree");
  }
  static void print(List l) {
    Console.WriteLine("List");
  }
  static void Main() {
    print(new OList());
  }
}
```

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```

extends `List`, coerces to `BinTree`

coerces to `List`

```
class List {...}
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  implicit operator BinTree(OList l) {...}
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class BinTree {
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```

extends `List`, coerces to `BinTree`

coerces to `List`

prints `BinTree`

Pitfalls with coercion

- Implicit computation
- Weaker type checking
- Object identity not preserved
- Value not preserved
- Multistep conversion
- Interaction with overloading
- Interaction with subtyping
- User-defined coercion

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coercion is a type relation; maintain “homomorphism”

prefer subtyping; determine statically

Pitfalls with coercion

- Implicit computation
- Weaker type checking
- Object identity not preserved
- Value not preserved
- Multistep conversion
- Interaction with overloading
- Interaction with subtyping
- User-defined coercion

many subtle issues;
use sparingly

Fortress

- Language for scientific computing
- Mathematical syntax
- Growable
  - everything in libraries (when possible)
  - rich type system
  - very primitive basic types
- Support for parallelism/data distribution

Fortress syntax

```
REAL(4)/REAL(3)*pi*r**3
```

$$\frac{4}{3}\pi r^3$$

Fortress syntax

```
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```

$$\frac{4}{3}\pi r^3$$

Basic numeric types are in libraries:
Need user-defined coercion.

Fortress type system

- Trait-based type system
  - supports multiple inheritance of code
  - no inheritance from object trait types
  - traits can exclude other traits
    - object trait types exclude all types other than supertypes
- Overloading for functions/methods
  - symmetric multiple dispatch
  - ambiguous calls prohibited at definition site

Fortress type system

```
trait A
  f(x: A) = “aa”
  f(x: B) = “ab”
end
trait B extends A
  f(x: A) = “ba”
end
```

a.f(a) = “aa”

a.f(b) = “ab”

b.f(a) = “ba”

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b.f(b) = ??

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Fortress forbids this kind of ambiguity:
Must provide “disambiguating” declarations

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  f(x: A) = “aa”
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trait B extends A
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  f(x: B) = “bb”
end
```

a.f(a) = “aa”

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Fortress forbids this kind of ambiguity:
Must provide “disambiguating” declarations

Overloading

- Exclusion rule
  - > okay if any parameter types exclude each other
- Subtyping rule
  - > okay if all of one's parameter types are “more specific”
- Meet rule
  - > okay if “disambiguating declaration” is provided

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Coercion makes these rules more complicated!

Coercion in Fortress

- Defined in target type
  - must exclude source type
  - target type is less specific
  - not inherited
- Statically determine target type
- No cycles in subtyping/coercion relation
  - “more specific” is (partially) well-defined
- Revised exclusion and meet rules
- Widest-need evaluation

Coercion in Fortress

```
trait A end
object B(x: N) extends A end
object C(x: N)
  coerce(b: B) = C(0)
end
object D(x: N)
  coerce(a: A) = D(1)
  coerce(b: B) = D(2)
  coerce(c: C) = D(3)
end
```

```
object Tester(a: A)
  f(c: C): N = c.x
  f(d: D): N = d.x + 5
  run() = self.f(a)
end
```

What is Tester(B(6)).run()?

Coercion in Fortress

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object B(x: N) extends A end
object C(x: N)
  coerce(b: B) = C(0)
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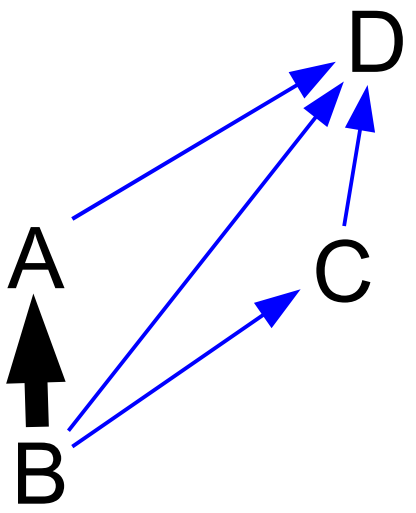

What is Tester(B(6)).run()?

Coercion in Fortress

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  coerce(a: A) = D(1)
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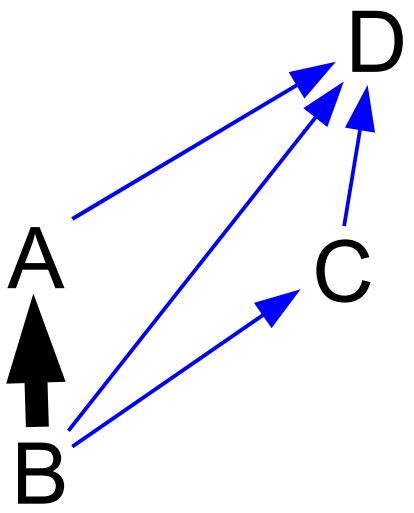

What is Tester(B(6)).run()? 7

Overloading with coercion

- Exclusion rule
  - okay if any parameter types exclude each other and no coercion between types
- Subtyping rule
  - okay if all of one's parameter types are “more specific” (by subtyping)
- Meet rule
  - okay if “disambiguating declaration” is provided (now must disambiguate coercions)

Conclusion

- Coercion should be used, but sparingly
  - > subtyping and overloading preferable
- Fortress has user-defined coercion
  - > strong restrictions (enforce no ambiguity)
  - > surprising uses

Come play with us:

http://research.sun.com/projects/plrg

http:///projectfortress.sun.com