And now for something completely different …

Today, you have been hearing about all sorts of clever new languages, language features, and uses of language features …

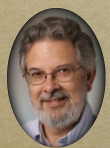
And now for something completely different …

Now, we are going to tell you about a boring language with no new language features, or uses of language features …

Grace

A New Educational Object-Oriented Programming Language

Andrew Black



Kim Bruce

James Noble

Suppose:

- You are going to teach object-oriented programming to 1st year students.
- What language would <u>you</u> choose?

Which language?

- ECOOP 2010: we don't like the available options
  - "Professional" languages too complex for teaching (Scala, C#, Java ...)
  - Smalltalk doesn't support static typing; Python has inconsistent method syntax, no encapsulation
- Group decision: design a modern object-oriented language specifically for teaching

High Level Goal

- "A Haskell for OO"
- Integrate proven newer ideas in programming languages into a simple language for teaching
  - language features represent key concepts cleanly
  - allow students to focus on the essential, rather than accidental, complexities of programming and modelling.

Objectives

- Low overhead for simple programs
  - Good IDE support for novices
- Simple semantic model
- Support a variety of approaches to teaching
  - Objects-first and objects-late
  - Untyped, Typeful and Gradually-typed
- Easy transition to other languages

Best of 20th Century-Technology

- Closures
- Assertions, unit testing, traces, and tools for finding errors
- High level constructs for concurrency
- Support for immutable data
- Generics (done right)

Influences

- Static world:
  - Eiffel, Java, C#, Scala, ...
- Dynamic world:
  - Smalltalk, Python, Scheme/Racket, ...

Simplest Programs

- Hello, World!

```
print "Hello, World"
```

- “Top level” code is considered to be inside the “default object”

```
object {
   print "Hello, World"
}
```

- An object with 0 methods and 1 statement

Object can contain code that is executed when created

Simple methods

- Methods can also be defined and used at the “top level”:

```
method celsiusToFahrenheit (temp) {
       ((temp * 9) / 5) + 32
}
print "20° Celsius is {celsiusToFahrenheit 20}° Fahrenheit"
```


Types are optional

- The same code with type annotations:

```
method celsiusToFahrenheit (temp: Number) -> Number {
       ((temp * 9) / 5) + 32
}
print "20° Celsius is {celsiusToFahrenheit 20}° Fahrenheit"
```

- Programmer decides whether typing is static, dynamic or ...
- All options are type-safe

Clean Concepts

- numbers

  23 2x10111 1.75 1.414214 -1 (all exact)

- methods on numbers

  20 + 43 7/4 20.factorial (all exact)

  2.sqrt π (approximate)

- Objects

```
object {
  method radius { 5 }
  method area { (radius^2)*π }
}
```


- constant binding

```
def cost = quantity * unitPrice

def disk = object {
  def radius = 5
  method area { (radius^2)*π }
}
```


- constants in objects are accessed as methods

```
disk.radius        answers 5
disk.area          answers ~78.53981...
```

- So, it doesn't matter if we define

```
def disk = object {
  def radius = 5
  method area { (radius^2)*π }}
```

or

```
def disk' = object {
  method radius { 5 }
  method area { (radius^2)*π }}
```

- variable binding

```
var sum := 0

var speed := 2

var invoiceDate := aDate.today
```

- methods and blocks can have temporary variables
- objects can have instance variables

- Instance variables

```
def adjustableDisk = object {
   var radius := 5
   method area { (radius^2)*π }}
```

- Instance variables bindings can be changed using methods (unless they are confidential):

```
adjustableDisk.radius := 1
```

the method is named "radius:="

- object factories:

```
def aDisk = object {
   method ofRadius(r) {
      object {
         method radius { r }
         method area { (radius^2)*π }
         method > (other) {
            radius > other.radius }
      }
   }
}

def myDisk = aDisk.ofRadius(7)

def yourDisk = aDisk.ofRadius(8)
```


- Classes codify factories:

```
class aDisk.ofRadius(r) {
         method radius { r }
         method area { (radius^2)*π }
         method > (other) {
            radius > other.radius }
      }

def myDisk = aDisk.ofRadius(7)

def yourDisk = aDisk.ofRadius(8)
```

- Object composition:

```
object {
    def hole = aDisk.ofRadius (h/2)
    def outside = aDisk.ofRadius (d/2)
    method area { outside.area - hole.area }
}

class aWasher.holeDiameter (h) outerDiameter (d) {
    def hole = aDisk.ofRadius (h/2)
    def outside = aDisk.ofRadius (d/2)
    method area { outside.area - hole.area }
}
```

Grace supports multipart method names (“mixfix”)

- Object inheritance:

```
def cylinder = object {
    inherits aDisk.ofRadius (r)
    def height = h
    method volume { area * height }
}

class aCylinder.baseRadius (r) height (h) {
    inherits aDisk.ofRadius (r)
    def height = h
    method volume { area * height }
}
```


- Returning multiple results

Grace does not support multiple results. But it’s easy to return an object:

```
method split (filename) {
    def dot = filename.indexOf(".")
    object {
        def base = filename.upto (dot-1)
        def extension = filename.from (dot+1)
    }
}
```

Grace answers an object with 2 methods

Closures

- With or without parameters:
  - { print "hello" }
  - { x,y -> print ("adding " ++ x ++ " to " ++ y ++ " gives " ++ (x+y))}
- represented by objects with “apply” method
  - object { method apply(x,y) { print ... }}
- Real lexical scope

Building Control Structures

- Closures support definition of control constructs in libraries:
  - class List {
        method forEach (actionClosure) {...}
    }
  - myList.forEach {x -> ...}

Delayed Evaluation Visible

if (someCond) then { C } else { D }

while { someCond } do { C }

if (someCond) then { C } else {
    {if (otherCond) { D } else { E }}

Other Grace Features

- Types (= interfaces) ≠ classes
- Visibility: public & confidential
- Support for immutable objects
- Equals & hashcode built-in (like Eclipse)
- Number consists of Rationals & Binary64 floats

Typing Disciplines

- Experimentalist (flower child):
  - Dynamic typing: Do what you want — we'll make sure it's safe at run-time ...
- TRC regulated:
  - Static typing: We'll make sure everything is safe before we let you do it.
- But semantics of type-safe programs are same either way.
  - ... though some may not be allowed by TRC.

All Disciplines Interoperate

- Mixing disciplines helps students/programmers migrate from dynamically to statically typed languages.
- What does a type annotation mean in a dynamically typed language?
  - Represents a claim - generates a dynamic check
  - like "assert s.nonempty"
- What does a type annotation mean in a statically typed language?
  - Represents provably correct assertion

Advanced Features

Pattern Matching

```
method matchTest (x: Number) {
    match(x)
        case {1 -> "one"}
        case {2 -> "two"}
        case {_ -> "lots"}
}
```


Variant Types

- Object types don't contain null value
  - Avoid Hoare's "billion dollar mistake"
- Construct as needed from singleton and variant types:
  - def notThere = object { method asString {...}...}
  - type Result = String | notThere

Using a variant

```
method doSomething(key: KeyType) {
  match(table.valueOf(key))
     case {v:String ->
               out.println(... ++ v)
               lastValue := v
     case {notThere ->
               out.println(... ++ " is empty")
     }
}
```

Provide more powerful pattern matching?

Language Levels

- Accomplished via libraries
- Libraries package together classes and objects
  - "use" object or class ⇒ inherit public features
- Need to develop useful pedagogical IDEs

Why Consider Using Grace?

- Clean Syntax
- Simple uniform semantic model
  - no static features, no overloading, no null, etc.
  - Everything is an object (even lambdas)
- Modern features
  - Generics done right, closures, case/pattern matching
  - Syntax supporting design of control structures

Why Consider Using Grace?

- Easy transition between dynamic & static type-checking
- High level support for parallelism and concurrency (planned)
  - Likely adopt concurrency constructs similar to those in Habanero Java at Rice:
    - async{stmts}, finish {stmts}, futures f := async{...}, forall(...) {stmts}, isolated{stmts}
  - Support for immutable objects

Current State of Grace

- 2011: 0.1, 0.2 and 0.3 language releases, prototype implementations ✔
  - 3 implementations in progress, spec at 0.35
- 2012: 0.8 language spec, mostly complete implementations
- 2013: 0.9 language spec, reference implementation, experimental classroom use
- 2014: 1.0 language spec, robust implementations, textbooks, initial adopters for CS1/CS2
- 2015: ready for general adoption

Help!

- Supporters
- Programmers
- Implementers
- Library Writers
- IDE Developers!!!!
- Testers
- Teachers
- Students
- Tech Writers
- Textbook Authors
- Blog editors
- Community Builders

- Information, blog, discussion:

  http://www.gracelang.org

- Try Grace in your browser:

  http://homepages.ecs.vuw.ac.nz/~mwh/minigrace/js/