Supporters

- Peter Andreae, Victoria University of Wellington
- Gilad Bracha, Ministry of Truth
- John Boyland, University of Wisconsin, Milwaukee
- Pascal Constanza, Vrije Universiteit Brussel
- Sophia Drossopoulou, Imperial College, London
- Susan Eisenbach, Imperial College, London
- Michael Hicks, University of Maryland
- Michael Kölling, University of Kent at Canterbury
- Gary Leavens, University of Central Florida
- Shane Markstrum, Bucknell University
- Doug Lea, SUNY Oswego
- Dirk Riehle, Friedrich-Alexander-University of Erlangen-Nürnberg
- Ewan Tempero, The University of Auckland
- Dave Thomas, Bedarra Research Labs
- Laurence Tratt, Middlesex University
- Jan Vitek, Purdue University
Design by a really small committee

Supported by a wide community

Public Blog: http://www.gracelang.org
Obvious Questions:

- What is an educational language?
- Why not use a “real” language?
- Why not Java? Scala? Python?
- Why now?

Non-Questions:

- why start with objects?
- why teach objects at all?
What is an educational programming language?

- Designed specifically for novices
- Can have limited or broad domain of application
  - We are interested in broad domain
- Main focus is on programming in the small, but some modularity features.
Teach Industrial- Strength Languages?

- Too much conceptual redundancy
- High overhead for simple programs
- Too hard to read and write
- Conceptual clarity sacrificed for practicality
- Saddled w/backward compatibility
Why Not Java?

- Overloading
- Confusing subtyping with inheritance
- No user-defined operators
- Primitive & Object types
- No lambdas
- Weak support for Generics
- Covariant arrays
- Equality not automatic
- No definable control structures
- Synchronized
Why Not Scala?

- Too complex for novices
- Multiple ways of doing everything
- Weak generics
- Powerful, but complex, type system
Why Not Python?

- Weak encapsulation
- Can’t teach typed programming
- Mismatch between method declarations & message sends
- __init__
- Implicit creation of fields
Why Now?

- Happy teaching Java next 3-5 years
- In 2015, Java will be 20 years old
- State of the art has advanced
  - patches look like ... patches
- New languages bring good ideas
  ... but are for professionals, not students
- To be ready in 2015, we need to start now.
Our User Model

- First year students in OO CS1 or CS2
  - objects early or late,
  - static or dynamic types,
  - functionals first or scriptings first or ...

- Second year students

- Faculty & TAs — assignments and libraries
We are in the dog food business

User model:
Beginning students

Customer:
Experienced instructors

The consumer is not the customer
The Big Question

What do we hope the students learn?

1. To program well in Grace?
2. To understand and use the o-o model?
3. To be prepared for other languages and models?

My position: 3 is less important than 1 and 2
Features

- Uncluttered code; layout significant
- Structural typing
- Local type inference
- Subtyping separated from inheritance
- User-definable operators
- Sensible generics
- Lambdas

- Allows both static and dynamic typing
- Parallel programming
- Equals & hashcode work automatically
- v instead of getV() for access
- Minimize “incantations”

public static void main
Warning!
Warning!

Design is in early phases
Warning!

- Design is in early phases
- Ambitious goals
Warning!

- Design is in early phases
- Ambitious goals
- Still disagree on many details
Grace Fundamentals

- Everything is an object
- Simple method dispatch
- Single inheritance via cloning and concatenation
- Language levels for teaching
- Extensible via Libraries (control & data)
- Java / C / Python / Scala programmers should be able to read Grace programs
Simple Grace Example

```grace
method average -> Number
// reads numbers from this stream and averages them
{
  var total := 0
  var count := 0
  until {atEnd} do {
    count := count + 1
    total := total + readNumber
  }
  if (count = 0) then {return 0}
  return total / count
}
```
method average -> Number
// reads numbers from this stream and averages them
{
  var total := 0
  var count := 0
  until {atEnd} do {
    count := count + 1
    total := total + readNumber
  }
  if (count = 0) then {return 0}
  return total / count
}
method average -> Number
  // reads numbers from this stream and averages them
  { var total := 0
    var count := 0
    until {atEnd} do {
      count := count + 1
      total := total + readNumber
    }
    if (count = 0) then {return 0}
    return total / count }
method average -> Number
// reads numbers from this stream and averages them
{
  var total := 0
  var count := 0
  until {atEnd} do {
    count := count + 1
    total := total + readNumber
  }
  if (count = 0) then {return 0}
  return total / count
}
method average -> Number
// reads numbers from this stream and averages them
{  var total := 0
  var count := 0
  until {atEnd} do {
    count := count + 1
    total := total + readNumber
  }
  if (count = 0) then {return 0}
  return total / count }
Everything is an Object

- except for methods
- Functions are objects
  - as in Smalltalk, lambda expressions create objects that mimic functions

```const welcomeAction := { print "Hello" }```
Everything is an Object

- except for methods
- Functions are objects
  - as in Smalltalk, lambda expressions create objects that mimic functions

const welcomeAction := { print "Hello" }
Everything is an Object

- except for methods

- Functions are objects

  as in Smalltalk, lambda expressions create objects that mimic functions

```const welcomeAction := { print "Hello" }```

```object { method apply
  { print "Hello" } }```
Everything is an Object

- except for methods
- Functions are objects
  - as in Smalltalk, lambda expressions create objects that mimic functions

```const welcomeAction := { print "Hello" }```
Everything is an Object

- except for methods
- Functions are objects
- as in Smalltalk, lambda expressions create objects that mimic functions

const welcomeAction := { print "Hello" }
Everything is an Object

- except for methods
- Functions are objects
- as in Smalltalk, lambda expressions create objects that mimic functions

```javascript
const welcomeAction := { print "Hello" }
```

```javascript
welcomeAction.apply
```
Everything is an Object

- except for methods
- Functions are objects
  - as in Smalltalk, lambda expressions create objects that mimic functions

```const welcomeAction := { print "Hello" }```
Everything is an Object

- except for methods
- Functions are objects
  - as in Smalltalk, lambda expressions create objects that mimic functions

```javascript
const orderingFunction := { a, b → a.name ≤ b.name }
```
Everything is an Object

- except for methods
- Functions are objects

as in Smalltalk, lambda expressions create objects that mimic functions

```javascript
const orderingFunction := { a, b → a.name ≤ b.name }
```
Everything is an Object

- except for methods
- Functions are objects
- as in Smalltalk, lambda expressions create objects that mimic functions

```plaintext
const orderingFunction := { a, b → a.name ≤ b.name }

object { method apply(a, b) {
  a.name ≤ b.name
} }
```
Everything is an Object

- except for methods
- Functions are objects
  - as in Smalltalk, lambda expressions create objects that mimic functions

```javascript
const orderingFunction := { a, b → a.name ≤ b.name }
```
Everything is an Object

- except for methods

- Functions are objects

  - as in Smalltalk, lambda expressions create objects that mimic functions

```javascript
const orderingFunction := { a, b → a.name ≤ b.name }
```
Everything is an Object

- except for methods
- Functions are objects
  - as in Smalltalk, lambda expressions create objects that mimic functions

```javascript
const orderingFunction := { a, b → a.name ≤ b.name }

if orderingFunction.apply(x, y) then { ... }
```
Everything is an Object

- except for methods
- Functions are objects
  - as in Smalltalk, lambda expressions create objects that mimic functions

```javascript
const orderingFunction := \{ a, b \to a.name \leq b.name \}
```
Everything is an Object

- But every object is not an instance of a class
- Instead: objects are self-contained
- Objects are created by executing an object constructor:

```object
const x: Number := 2
const y: Number := 3
method distanceTo other: Point → Number {
  ((x - other.x)^2 + (y - other.y)^2)
}
```
object {
    const x:Number := 2
    const y:Number := 3
    method distanceTo other:Point → Number {
        ((x - other.x)^2 + (y - other.y)^2) }
}
object {
  const x:Number := 2
  const y:Number := 3
  method distanceTo other:Point → Number {
    ((x - other.x)^2 + (y - other.y)^2) 
  }
}
object {
    const x:Number := 2
    const y:Number := 3
    method distanceTo other:Point → Number {
        ((x - other.x)^2 + (y - other.y)^2) }
}

Design Decisions:

- fields and methods share the same namespace
- p.x might be a field access or a method request
- the implementation can replace a field by a method without the client knowing
What about classes?

**Pro**
- Instructors are familiar with classes
- Classes capture a common pattern: a "factory" object that makes similar "instance" objects
- Brevity

**Con**
- Unnecessary — just use objects
- The common pattern usually lies in some way
- Restrictive, e.g. Smalltalk’s parallel hierarchies
Compromise Design

Grace has classes; they resemble a block containing an object constructor.

We try to make the syntax familiar, but not so familiar that we lie.

Classes are restrictive, but the full power of object constructors is available to implement the general case.
Point Class

const Point := class { x': Number, y':Number →
    const x:Number := x'
    const y:Number := y'
    method distanceTo other:Point → Number {
        ((x - other.x)^2 + (y - other.y)^2) }
}
Point Class

const Point := class { x': Number, y':Number →
const x:Number := x'
const y:Number := y'
method distanceTo other:Point → Number {
  ((x - other.x)^2 + (y - other.y)^2) }
}
Point Class

class Point { x': Number, y':Number →
  const x:Number := x'
  const y:Number := y'
  method distanceTo other:Point → Number {
    ((x - other.x)^2 + (y - other.y)^2) 
  }
}

new(x',y')
Point Class

const Point := class { x’: Number, y’:Number →
  const x:Number := x’
  const y:Number := y’
  method distanceTo other:Point → Number {
    ((x - other.x)^2 + (y - other.y)^2) }
  }

const Point = object {
    method new (x’:Number, y’:Number) {
        object {
            const x:Number := x’
            const y:Number := y’
            method distanceTo other:Point → Number {
                ((x - other.x)^2 + (y - other.y)^2) }}
    }
}
const Point := class { x': Number, y':Number →
    const x:Number := x'
    const y:Number := y'
    method distanceTo other:Point → Number {
        ((x - other.x)^2 + (y - other.y)^2) }
}
One true message send

Like Smalltalk and Self:

- no overloading
- "method request" names the method and provides the arguments
- "dynamic dispatch" selects the correspondingly-named method in the receiver
- "method execution" occurs in the receiver
- field access is via methods
One true message send

Like Smalltalk and Self:

- no overloading
- "method request" names the method and provides the arguments
- "dynamic dispatch" selects the correspondingly-named method in the receiver
- "method execution" occurs in the receiver
- field access is via methods

(I'm trying to learn not to say "message-send" or "method call".)
Example: a Contact Object

```javascript
const andrewInfo := object {
    var firstName := "Andrew"
    const lastName := "Black"
    method printOn s:Stream {
        s.puts firstName
        s.puts " 
        s.puts lastName
    }
}
```
Example: a Contact Object

const andrewInfo := object {
  var firstName := "Andrew"
  const lastName := "Black"
  method printOn s:Stream {
    s.puts firstName
    s.puts ' '
    s.puts lastName
  }
}
Example: a Contact Object

const andrewInfo := object {
  var firstName := "Andrew"
  const lastName := "Black"
  method printOn s:Stream {
    s.puts firstName
    s.puts " 
    s.puts lastName
  }
}

Creates 2 methods: firstName and firstName:=

Creates a method lastname
const andrewInfo := object {
    privar ¿firstName?
    method firstName -> String { ¿firstName? }
    method firstName:= s:String { ¿firstName? := s }
    ¿firstname? := "Andrew"
    priconst ¿lastName?
    method lastName -> String { ¿lastName? }
    ¿lastname? := "Black"
    method printOn s:Stream {
        s.puts firstName
        s.puts ' '
        s.puts lastName
    }
}
Contact Object Expanded

const andrewInfo := object {
    privar ¿firstName?
    method firstName -> String { ¿firstName? }
    method firstName:= s:String { ¿firstName? := s }
    ¿firstname? := "Andrew"
    priconst ¿lastName?
    method lastName -> String { ¿lastName? }
    ¿lastname? := "Black"
    method printOn s:Stream {
        s.puts firstName
        s.puts ' '
        s.puts lastName }
}
const contact := object {
    method named (first, last) -> Contact {
        object {
            var firstName:String := first
            var lastName:String := last
            method printOn s:Stream {
                s.puts firstName
                s.puts ''
                s.puts lastName
            }
        }
    }
}

const database := MutableSequence.empty

method add c:Contact {
    database addLast c
}
Contact Factory

const contact := object {
  method named (first, last) -> Contact {
    object {
      var firstName: String := first
      var lastName: String := last
      method printOn s: Stream {
        s.puts firstName
        s.puts ' '
        s.puts lastName
      }
    }
  }
  const database := MutableSequence.empty
  method add c: Contact {
    database addLast c
  }
}

attributes of the outer "factory" object
Contact Factory

const contact := object {
    method named (first, last) -> Contact {
        object {
            var firstName:String := first
            var lastName:String := last
            method printOn s:Stream {
                s.puts firstName
                s.puts '
                s.puts lastName }
        }
    }
}
class Database {
    const database := MutableSequence.empty
    method add c:Contact {
        database addLast c }
}
}
Contact Factory

const contact := object {
  method named (first, last) -> Contact {
    object {
      var firstName:String := first
      var lastName:String := last
      method printOn s:Stream {
        s.puts firstName
        s.puts ' '
        s.puts lastName
      }
    }
  }
}

const database := MutableSequence.empty
method add c:Contact {
  database addLast c
}

returns a contact object initialized to (first, last)
const contact := object {
    method named (first, last) -> Contact {
        object {
            var firstName:String := first
            var lastName:String := last
            method printOn s:Stream {
                s.puts firstName
                s.puts ''
                s.puts lastName }
        }
    }
}
const database := MutableSequence.empty
method add c:Contact {
    database addLast c }
}
Sample client code

```go
const host := contact.named("Graham", "Hutton")
const guest := contact.named("Andrew", "Black")
contact.database.add host
go
contact.database.add guest
```
Grace's inheritance story is based on an old idea of Taivalsaari

Cloning + Concatenation = inheritance

Delegation versus concatenation
or cloning is inheritance too

Antero Taivalsaari
University of Jyväskylä, Finland
tsaari@jyu.fi

In this paper a simple prototype-based model of object-oriented programming is introduced. Unlike previous prototype-based systems, which use delegation to achieve incremental modification of objects, the suggested model is based on concatenation: linear composition of object interfaces. The model eliminates the notions of delegation and parent slots from prototype-based programming, and shows that the essence of object-oriented programming can be captured using only a small number of user-level language constructs.

1. Introduction

Object-oriented systems are typically based on classes. Classes are descriptions of objects capable of serving as templates from which instances, the actual objects described by classes, can be instantiated. In class-based systems, new kinds of objects are created...
Suppose that we have an object:

andrewInfo

<table>
<thead>
<tr>
<th>first Name</th>
<th>last Name</th>
<th>printOn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&quot;Andrew&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;Black&quot;</td>
</tr>
</tbody>
</table>
Suppose that we have an object:

```
andrewInfo
```

<table>
<thead>
<tr>
<th>first Name</th>
<th>last Name</th>
<th>last Name:</th>
<th>printOn</th>
<th>&quot;Andrew&quot;</th>
<th>&quot;Black&quot;</th>
</tr>
</thead>
</table>

We want to add a telephone number. The "delta" is:
Suppose that we have an object:

```
andrewInfo
```

| first Name | last Name | printOn | last Name:= | "Andrew" | "Black"
|------------|-----------|---------|-------------|---------|---------|

We want to add a telephone number. The "delta" is:

```
andrewPhone
```

| work phone | work phone:= | "+1 503 725 2411"
|------------|--------------|-------------|
Suppose that we have an object:

```
andrewInfo
```

| first Name | last Name | last Name: | printOn | "Andrew" | "Black"
|------------|-----------|------------|---------|----------|----------|

We want to add a telephone number. The "delta" is:

```
andrewPhone
```

| work phone | work phone:= | "+1 503 725 2411"
|------------|--------------|-------------|

1. Clone both objects
Suppose that we have an object:

```
andrewInfo
```

| first Name | last Name | last Name: | printOn | "Andrew" | "Black"
|------------|-----------|------------|---------|----------|----------

We want to add a telephone number. The "delta" is:

```
andrewPhone
```

| work phone | work phone: | "+1 503 725 2411"
|------------|-------------|--------------

1. Clone both objects
Suppose that we have an object:

```
andrewInfo
```

We want to add a telephone number. The "delta" is:

```
andrewPhone
```

1. Clone both objects
2. Concatenate the copies
### andrewInfo

<table>
<thead>
<tr>
<th>first Name</th>
<th>last Name</th>
<th>last Name:</th>
<th>printOn</th>
<th>&quot;Andrew&quot;</th>
<th>&quot;Black&quot;</th>
</tr>
</thead>
</table>

### andrewPhone

<table>
<thead>
<tr>
<th>work phone</th>
<th>work phone:</th>
<th>&quot;+1 503 725 2411&quot;</th>
</tr>
</thead>
</table>

### andrewPhone extends andrewInfo

<table>
<thead>
<tr>
<th>work phone</th>
<th>work phone:</th>
<th>&quot;+1 503 725 2411&quot;</th>
<th>first Name</th>
<th>last Name</th>
<th>last Name:</th>
<th>printOn</th>
<th>&quot;Andrew&quot;</th>
<th>&quot;Black&quot;</th>
</tr>
</thead>
</table>
In code:

```plaintext
const andrewInfo := object {
  var firstName := "Andrew"
  const lastName := "Black"
  method printOn s:Stream {
    s.puts firstName
    s.puts ' '
    s.puts lastName
  }
}

const andrewPhone := object {
  var officePhone := "503 725 2411"
}

const andrewPhoneInfo := andrewPhone extends andrewInfo
```
No need to name intermediate objects:

```javascript
const andrewPhoneInfo := object {
  var officePhone := "503 725 2411"
}
```
Notice what this means:

- clone means shallow copy:
- new object gets copies of the fields and the methods of the original objects
- it’s possible for an object to have two or more methods with the same name
const andrewPhoneInfo := object {
    var officePhone := "503 725 2411"
    method printOn s:Stream {
        super.printOn s
        s.puts ' ' 
        s.puts officePhone
    }
} extends contact.new ("Andrew", "Black")
andrewPhoneInfo

| work phone | work phone: | "+1 503 725 2411" | printOn |

| first Name | last Name | last Name: | printOn | "Andrew" | "Black" |
```java
method printOn s:Stream {
    super.printOn s
    s.puts ' '
    s.puts officePhone
}
```

- **first Name**: "Andrew"
- **last Name**: "Black"
- **work phone**: "+1 503 725 2411"
method printOn s:Stream {
    super.printOn s
    s.puts ' '
    s.puts officePhone
}

super.printOn means the next printOn in the object

work phone := "+1 503 725 2411"

first Name := "Andrew"
last Name := "Black"
last Name :=
printOn

andrewPhoneInfo
andrewPhoneInfo

```
method printOn s:Stream {
    super.printOn s
    s.puts ' ' 
    s.puts officePhone
}
```

super.printOn means the next printOn in the object
andrewPhoneInfo

<table>
<thead>
<tr>
<th>first Name</th>
<th>last Name</th>
<th>last Name:</th>
<th>printOn</th>
<th>work phone:</th>
<th>work phone:</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Andrew&quot;</td>
<td>&quot;Black&quot;</td>
<td>&quot;Andrew&quot;</td>
<td>&quot;Black&quot;</td>
<td>&quot;+1 503 725 2411&quot;</td>
<td>&quot;+1 503 725 2411&quot;</td>
</tr>
</tbody>
</table>

method printOn s:Stream {
   super.printOn s
   s.puts " 
   s.puts officePhone
}

super.printOn means the next printOn in the object
andrewPhoneInfo

work phone := "+1 503 725 2411"

First Name := "Andrew"

Last Name := "Black"

work phone

next might be a better keyword than super
Not your Grandfather’s Inheritance
Not your Grandfather’s Inheritance

What’s more important:

To have a simple, explicable, inheritance story?

To have an inheritance story that’s like the mainstream languages of the 1990’s?
Not your Grandfather’s Inheritance

What’s more important:

- To have a simple, explicable, inheritance story?
- To have an inheritance story that’s like the mainstream languages of the 1990’s?

Or:

- Teachability, vs. familiar to instructors
Objects include data and actions

So it’s essential to be able to define new control operations on new objects

Example: a new kind of dictionary

It must be possible to define new iterators, lookups, etc. with a syntax that’s as convenient for the user as the “built in” objects
We achieve this!

- Nothing is built in!
- As in SELF, all built-in objects are really defined in libraries, including the Booleans.
- if <condition> then <block> else <block>, while <block> do <block>, and with <collection> do <block> are all method requests.
- The methods are defined on object Grace, and inherited by all other objects
object Grace := {
  method if c:Boolean
      then t:Block[\rightarrow \alpha]
      else f:Block[\rightarrow \alpha] \rightarrow \alpha {
          c ifTrue t ifFalse f }

  method while c:Block[\rightarrow Boolean]
      do a:NullaryBlock \rightarrow void {
          c.apply ifTrue { a.apply; while c do a }

  method until c:Block[\rightarrow Boolean]
      do a:NullaryBlock \rightarrow void {
          while {c.apply.not} do a }
}
object true := {
  method ifTrue t:Block\[\rightarrow\alpha\]
    ifFalse f:Block\[\rightarrow\alpha\] \rightarrow \alpha \{
      t.apply } } }

object false := {
  method ifTrue t:Block\[\rightarrow\alpha\]
    ifFalse f:Block\[\rightarrow\alpha\] \rightarrow \alpha \{
      f.apply } } }
object Grace = { ...
    method with c: Collection[ε]
        do a: Block[ε → void] { 
            c do a }
    method with c: Collection[ε]
        map a: Block[ε → α] → Collection[α] { 
            c collect a }
    method with c: Collection[ε]
        select a: Block[ε → Boolean] 
            → Collection[ε] { 
            c.select a }
}
class interval = {
  const start: Number
  const stop: Number
  const step: Number

  method do action: Block[Number → void] {
    var element
    var index := 0
    while {index < self size}
      do { element := start + (index × step)
        index := index + 1
        action.apply element
      } } }
What about case?

**Pro**
- Instructors are familiar with case
- Case is concise
- Students will meet case in other languages

**Con**
- Unnecessary — just use method dispatch
- Assume “open classes”
- Case violates object encapsulation
- “Tell, don’t ask”
What about case?

**Pro**
- Instructors are familiar with case
- Case is concise
- Students will meet case in other languages

**Con**
- Unnecessary — just use method dispatch
- Assume “open classes”
- Case violates object encapsulation
- “Tell, don’t ask”

Can we devise a simple, object-oriented dispatch?
What about case?

**Pro**
- Instructors are familiar with case
- Case is concise
- Students will meet case in other languages

**Con**
- Unnecessary — just use method dispatch
- Assume “open classes”
- Case violates object encapsulation
- “Tell, don’t ask”

Can we devise a simple, object-oriented dispatch? Should we?
How can we teach \texttt{case} without \texttt{case}?

- Add algebraic types and pattern matching?
- Adopt Newspeak-style quad-dispatch case?
- Scala case-classes?
The last 2 men standing...

- Pattern-matching through method dispatch (James Noble, via Gilad Bracha)

- Case as object (Andrew Black, via Blume, Acar & Chae)
Pattern-matching through method dispatch
Pattern-matching through method dispatch

matchPattern(p)

s:Scrutinee

p:Pattern
Pattern-matching through method dispatch

s: Scrutinee

matchObject(s)

matchPattern(p)

p: Pattern
Pattern-matching through method dispatch

matchObject does different things in different patterns:

- Type patterns ask s for its type
- Literal patterns check for =
- etc

matchObject(s)

matchPattern(p)

s: Scrutinee
Pattern-matching through method dispatch

matchPattern(p)

matchObject(s)

s: Scrutinee

p: Pattern
Pattern-matching through method dispatch

matchPattern(p)

matchObject(s)

s: Scrutinee

p: Pattern

extract
Pattern-matching through method dispatch

extract returns a tuple containing the "internal state" of the scrutinee

extract

matchObject(s)

matchPattern(p)

p:Pattern
Pattern-matching through method dispatch

s:Scrutinee

matchPattern(p)

matchObject(s)

extract

p:Pattern
Pattern-matching through method dispatch

- Treat any lambda-expression as a pattern
Case as Object

s:Scrutinee

c:caseObject
Case as Object

s:Scrutinee

match(c)

c:caseObject
Case as Object

s: Scrutinee

match(c)

branch\_i(internal state)

c: caseObject
Open Issues

- Statements as well as Expressions?
- case statement?
Open Issues

- Statements as well as Expressions?
- case statement?
- details of class syntax
Open Issues

- Statements as well as Expressions?
- case statement?
- details of class syntax
Open Issues

- Statements as well as Expressions?
- case statement?
- details of class syntax
Open Issues

- Statements as well as Expressions?
- case statement?
- details of class syntax
What have we decided?

- Types are optional
- Lambdas-expressions are supported
- Extensibility via libraries
- Types (= interfaces) are structural
- Classes define an interface corresponding to the operations on their instances
- Support for immutable objects
- Classes are open
Types are Optional

- This means more than inferring type declarations:
  - “Untyped semantics”: types don’t change the semantics of correct programs — and not the syntax either!
  - explicit type annotations are assertions

  - just like `assert s.isNotEmpty`
dynamic and static type-checking: two interpretations of the same program
dynamic and static type-checking: two interpretations of the same program

- The Laissez faire or George W. Bush interpretation:
  - do what you want, we won’t try to stop you. If you mess up, the PDIC will bail you out.
dynamic and static type-checking: two interpretations of the same program

- The Laissez faire or George W. Bush interpretation:
  - do what you want, we won’t try to stop you. If you mess up, the PDIC will bail you out.
dynamic and static type-checking: two interpretations of the same program

 Gib The Laissez faire or George W. Bush interpretation:

 do what you want, we won’t try to stop you. If you mess up, the PDIC will bail you out.

 Gib The “The Nanny State” or Harold Wilson interpretation.

 We will look after you. If it is even remotely possible that something may go wrong, we won’t let you try.
dynamic and static type-checking:
two interpretations of the same program

- The Laissez faire or George W. Bush interpretation:
- The “The Nanny State” or Harold Wilson interpretation.
A third interpretation is useful:

- The Laissez faire or George W. Bush interpretation:

- The “The Nanny State” or Harold Wilson interpretation.

- The “Proceed with caution”, or Edward R. Murrow, interpretation.

- The checker has been unable to prove that there are no type errors in your program. It may work; it may give you a run-time error. Good night and good luck.
Three interpretations

- Under all three interpretations, an error-free program has the same meaning.

- Under the Wilson interpretation:
  - some error-free programs won’t be permitted to run
  - an erroneous program will result in a checked run-time error.
Three interpretations

- Under all three interpretations, an error-free program has the same meaning.

- Under the Bush interpretation, all checks will be performed at runtime.

- Even those that are guaranteed to fail — because a counter-example is more useful than a type-error message.
Three interpretations

Under all three interpretations, an error-free program has the same meaning.

Under the Bush interpretation, all checks will be performed at runtime.

Under the Murrow interpretation, you will get a mix of compile-time warnings and run-time checks.

Under the Wilson interpretation, you won't be permitted to run a program that might have a type-error.
Help!

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

2011: 0.1, 0.2 and 0.5 language releases, hopefully prototype implementations

2012 0.8 language spec, some 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?
No conclusions — we aren't done yet

Questions
Comments
Suggestions
Brickbats