SubScript:
an ACP-based Extension to Scala

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Overview

- Programming is Still Hard
- Algebra of Communicating Processes
- SubScript Now
  - Scala Extension
  - Implementation
  - Debugger demo
- New Dataflow Constructs
  - One-time Flow
  - Lasting Flow
  - SubScript Actors
- Conclusion

Programming is Still Hard

Mainstream programming languages: imperative

- good in batch processing
- not good in parsing, concurrency, event handling
- Callback Hell

Neglected idioms

- Non-imperative choice: BNF, YACC
- Data flow: Unix pipes
- Process Algebra: ACP

Algebra of Communicating Processes - 1

Bergstra & Klop, Amsterdam, 1982 - ...

ACP~ Boolean Algebra

+	choice
·	sequence
0	deadlock
1	empty process

atomic actions a,b,…
parallelism
communication
disruption, interruption
time, space, probabilities
money
...

Algebra of Communicating Processes - 2

Less known than CSP, CCS

Specification & Verification

- Communication Protocols
- Production Plants
- Railways
- Coins and Coffee Machines
- Money and Economy

Strengths

- Familiar syntax
- Precise semantics
- Reasoning by term rewriting
- Events as actions

Algebra of Communicating Processes - 3

$$
\begin{aligned}
x+y &= y+x \\
(x+y)+z &= x+(y+z) \\
x+x &= x \\
(x+y)\cdot z &= x\cdot z+y\cdot z \\
(x\cdot y)\cdot z &= x\cdot(y\cdot z)
\end{aligned}
$$

$$
\begin{aligned}
0+x &= x \\
0\cdot x &= 0 \\
1\cdot x &= x \\
x\cdot 1 &= x
\end{aligned}
$$

$$
\begin{aligned}
(x+1)\cdot y &= x\cdot y + 1\cdot y \\
&= x\cdot y + y
\end{aligned}
$$

Algebra of Communicating Processes - 4

$$x \| y = x \between y + y \between x + x \mid y$$

$$(x+y) \between z = \ldots$$
$$a \cdot x \between y = \ldots$$
$$1 \between x = \ldots$$
$$0 \between x = \ldots$$

$$(x+y) \mid z = \ldots$$
$$\ldots = \ldots$$

ACP Language Extensions

- 1980: Jan van den Bos - Input Tool Model
- 1988-2011: AvD - Scriptic
  - Pascal, Modula-2, C, C++, Java
- 1994: Jan Bergstra en Paul Klint - Toolbus
- 2011-...: AvD - SubScript
  - Scala
  - JavaScript, ... (?)
- Application Areas
  - GUI Controllers
  - Text Parsers
  - Discrete Event Simulation
  - Dataflow Programming (?)
  - Parallel Processing (?)

SubScript Features

"Scripts" – process refinements as class members

```
script a = b; {c}
```

- Much like methods: override, implicit, named args, varargs, ...
- Invoked from Scala: `_execute(a, aScriptExecutor)`
  Default executor: `_execute(a)`
- Body: process expression
  Operators: `+ ; & | && || /` ...
  Operands: script call, code fragment, if, while, ...
- Output parameters: ?, ...
- Shared scripts:
  `script send,receive = {}`

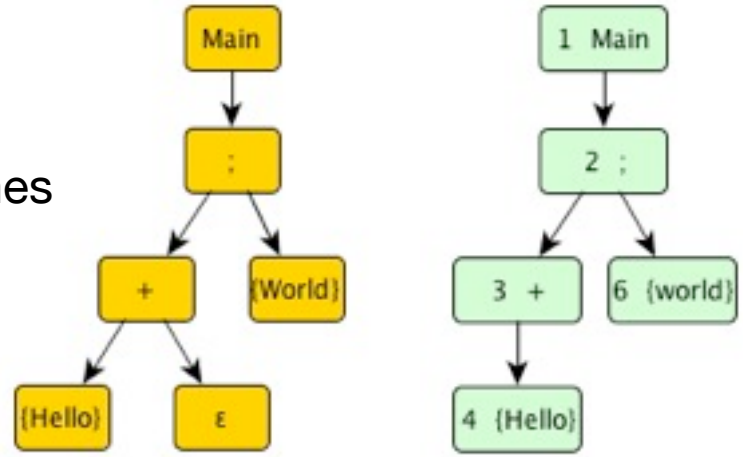
Implementation - 1

- Branch of Scalac: 1300 lines (scanner + parser + typer)

```
script Main = ({Hello} + ε); {World}
```

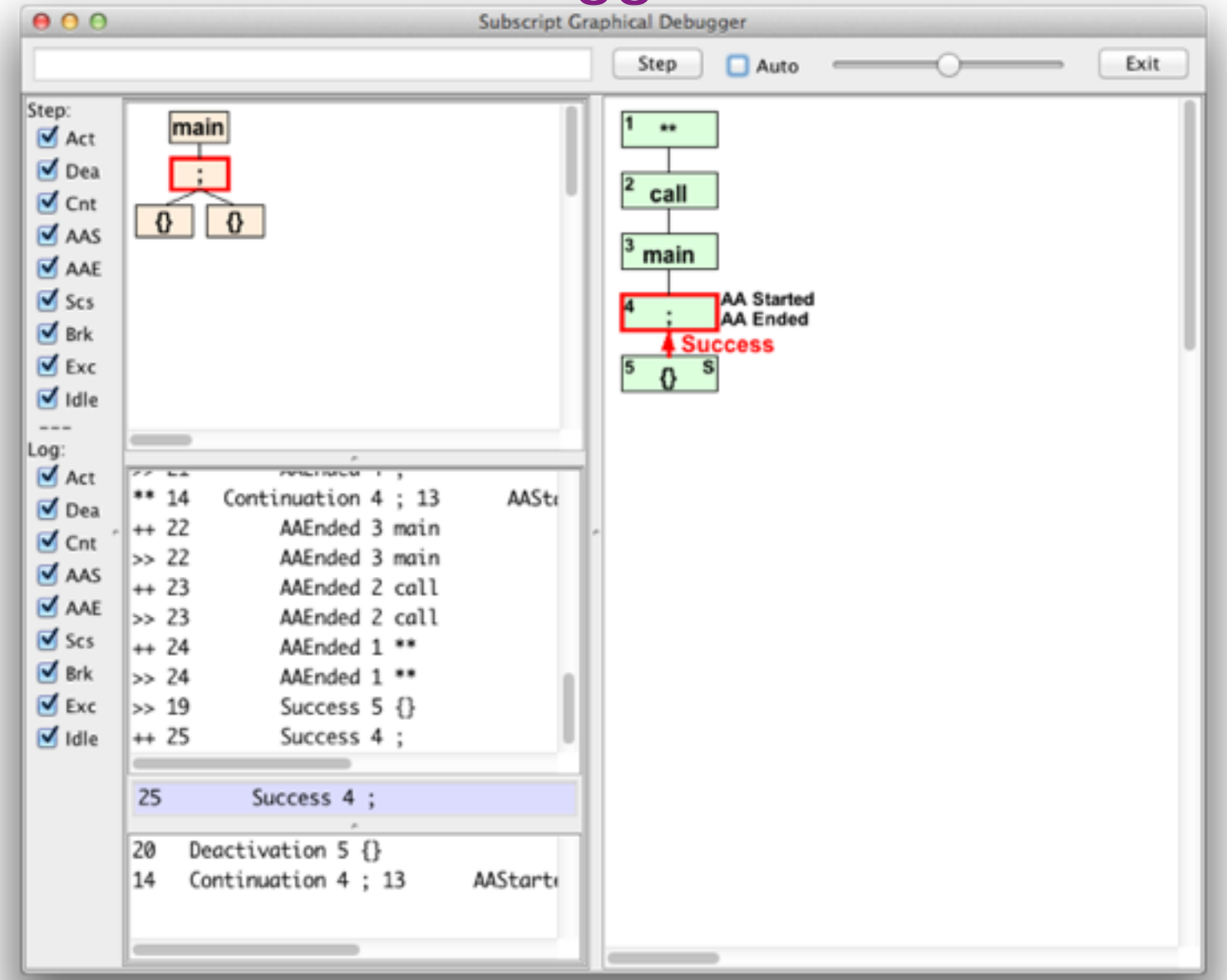
```
import subscript.DSL._
def Main = _script('Main) {
              _seq(_alt(_normal{here=>Hello}, _empty),
                        _normal{here=>World}           )
            }
```

- Virtual Machine: 2000 lines
  - static script trees
  - dynamic Call Graph



- Swing event handling scripts: 260 lines
- Graphical Debugger: 550 lines (10 in SubScript)

Debugger - 1


Subscript Graphical Debugger
Step
Auto
Exit
Step:
Act
Dea
Cnt
AAS
AAE
Scs
Brk
Exc
Idle
Log:
Act
Dea
Cnt
AAS
AAE
Scs
Brk
Exc
Idle
main
;
{}
{}
** 14 Continuation 4 ; 13
++ 22 AAEnded 3 main
>> 22 AAEnded 3 main
++ 23 AAEnded 2 call
>> 23 AAEnded 2 call
++ 24 AAEnded 1 **
>> 24 AAEnded 1 **
>> 19 Success 5 {}
++ 25 Success 4 ;
25 Success 4 ;
20 Deactivation 5 {}
14 Continuation 4 ; 13
1 **
2 call
3 main
4 ;
AA Started
AA Ended
Success
5 {}
S

Debugger - 2

built using SubScript

```
live        = stepping || exit

stepping    = {* awaitMessageBeingHandled *}
              if (shouldStep)
              (  @gui: {! updateDisplay !} stepCommand
              || if (autoCheckBox.isChecked) waitForStep
              )
              { messageBeingHandled = false }
              ...

exit        = exitCommand
              var     isSure = false
              @gui: { isSure = confirmExit }
              while (!isSure)

exitCommand = exitButton + windowClosing
```

One-time Dataflow - 1

```
exit    = exitCommand
          var     isSure = false
          @gui: { isSure = confirmExit }
          while (!isSure)

exit    = exitCommand; confirmExit ==> while(!_)
```

- Script result type `script confirmExit:Boolean = ...`
- Result values `$ confirmExit^` `$confirmExit`
- Script Lambda's `<b:Boolean => while(!b)>`
- `x==>y` definition `do_flowTo(<x^>,<y^>)`

```
do_flowTo[T,U](s:script[T],t:T=>script[U]): U = s then t($s)^
```

One-time Dataflow - 2

```
val f: Future[List[String]] = future {session.getRecentPosts}

f onComplete {
  case Success(posts) => for (post <- posts) println(post)
  case Failure(t) => println("An error has occured: " + t.getMessage)
}
```

```
f ==> {for (post <- _) println(post)}
 =/=> {println("An error has occured: " + _.getMessage)}
```

Implemented using implicit script conversion

+ ==>...=/=>
+ failure exception values ($$)

One-time Dataflow - 3

```
val f: Future[List[String]] = future {session.getRecentPosts}

f onComplete {
  case Success(posts) => for (post <- posts) println(post)
  case Failure(t) => println("An error has occured: " + t.getMessage)
}
```

```
implicit script future2script[F:Future[F]](f:F)
= @{f onComplete {case Success(t) =>  $ = t; there.succeed
                  case Failure(t) => $$ = t; there.fail   }}: {. .}
```

```
x==>y=/=>z
```
definition:
```
do_flowTo_else(<x^>,<y^>,<z^>)
```

```
do_flowTo_else[T,U](s:script[T],
                    t:T=>script[U],
          u:Throwable=>script[U]): U = s then t($s)^ else u($$s)^
```

Lasting Dataflow - 1

```
def copy(in: File, out: File): Unit = {

  val  inStream = new  FileInputStream(in)
  val outStream = new FileOutputStream(out)

  val eof = false
  while (!eof) {
    val b = inStream.read()
    if (b==-1) eof=true
    else outStream.write(b)
  }

   inStream.close()
  outStream.close()
}
```

Lasting Dataflow - 2

```
fileCopier(in:File, out:File)   =   reader(in) &==> writer(out)

reader(f:File)   = val inStream = new FileInputStream(f);
                   val b = inStream.read()  <=b   while (b!=-1);
                   inStream.close

writer(f:File)   = val outStream = new FileOutputStream(f);
                   =>?i: Int   while (i!=-1)    outStream.write(i);
                   outStream.close

   <==>(i:Int)  = {}
```

Lasting Dataflow - 3

```
fileCopier  (in:File, out:File) = reader,in &==> writer,out

fileCrFilter(in:File, out:File) = reader,in &==> crFilter
                                  &==> writer,out

crFilter  =  =>?c:Int  if(c!='\r') <=c  ...
```

Performance ~ 50 k actions / second

Optimization?

SubScript Actors: Ping Pong

```
class Ping(another: ActorRef) extends Actor {

override def receive: PartialFunction[Any,Unit] = {case _ =>}

     another ! "Hello"
     another ! "Hello"
     another ! "Terminal"
}

class Pong extends SubScriptActor {

  implicit script str2rec(s:String) = << s >>

  script ..
    live = "Hello" ... || "Terminal" ; {println("Over")}
}
```

SubScript Actors: Partial scripts - 1

```
def receive = {case Request   (r) => sender ! calculate(r)
               case Shutdown      => context.stop(self)
               case Dangerous (r) => a.tell(Work(r),sender)
               case OtherJob  (r) => a!JobRequest(r,sender)
               case JobReply(r,s) => s ! r
}
```

```
  live = .. << case Request   (r) => sender ! calculate(r)
               case Dangerous (r) => a.tell(Work(r),sender)
               case OtherJob  (r) => a!JobRequest(r,sender)
               case JobReply(r,s) => s!r
            >>
       ;    << Shutdown >>
```

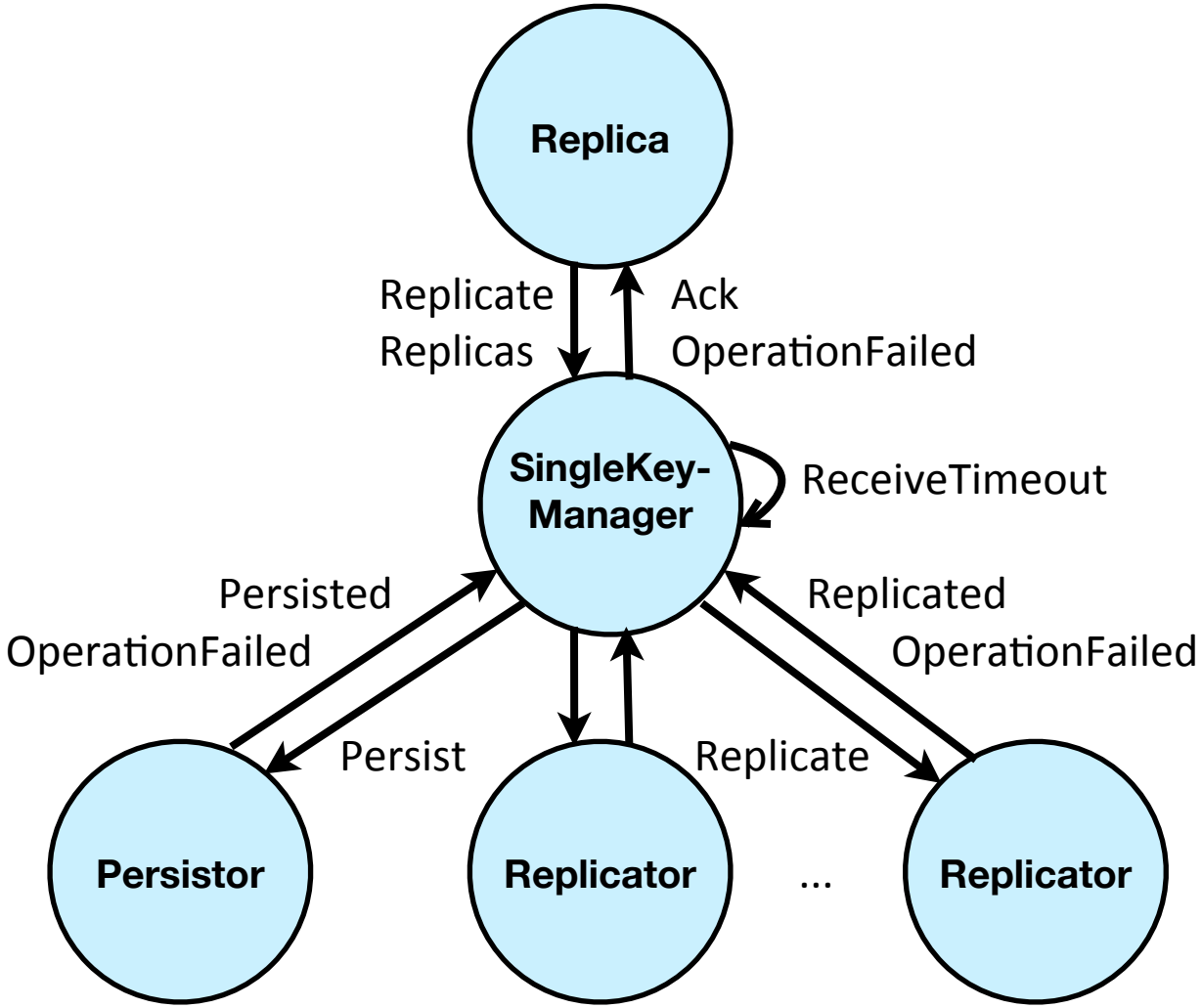
SubScript Actors: Partial scripts - 2

```
var initializationReady = false
var activeActors        = 0
var sum: Double         = 0

def receive = {
  case context: Context =>
    sum = 0 //reset the instance variables
    activeActors = 0
    for(task <- context.tasks) {
      val actor = actorOf[Delegate].start
      actor ! DoTask(task)
      activeActors += 1
    }
    initializationReady = true

  case delegateResult: Double =>
    sum += delegateResult; sender.get.stop
    activeActors -= 1
    if(initializationReady && activeActors<=0) {
      clientActor ! sum
}   }
```

SubScript Actors: Partial scripts - 3

```
live = ...
       << context: Context
         ==> var sum: Double = 0
             ( for(task <- context.tasks)
             & {!val actor = actorOf[Delegate].start
                 actor ! DoTask(task) !}
               << d:Double => sum+=d; sender.get.stop >>
             )
             {clientActor ! sum}
       >>
```

Akka Actors: KV-Store Assignment - 1



Akka Actors: KV-Store Assignment - 2

```
class SingleKeyManager(key: String) extends Actor { // 44 lines

  var replicatorsOutstandingAck = Set.empty[ActorRef]
  var persistenceOutstandingAck = false
  var outstandingAckId = 0L
  var outstandingValueOption: Option[String] = None
  var ackActor: ActorRef = self // null considered bad
  var ackMsg  :   AnyRef = self
  var repMsg  :   AnyRef = self
  var retriesDone = 0

  var timoutForPersistenceFailure = 100.milliseconds
  var timoutForPersistenceGiveup  =   1.seconds
  var retriesForGiveup = timoutForPersistenceGiveup / timoutForPersistenceFailure

  def checkReady() = {
    if (!persistenceOutstandingAck
    && replicatorsOutstandingAck.isEmpty) {
      ackActor ! ackMsg
      context.setReceiveTimeout(Duration.Undefined)
    }
  }
  def sendMsgToPersistorAndReplicators() = {
    if (persistenceOutstandingAck)
        persistor ! Persist(key, outstandingValueOption, outstandingAckId)
    replicatorsOutstandingAck.foreach(_ ! repMsg)
  }

  def receive: Receive = ~~~
}
```

Akka Actors: KV-Store Assignment - 3

```
class SingleKeyManager(key: String) extends Actor { // 44 lines
  ~~~
  def receive: Receive = LoggingReceive{
    case (r@Replicate(key, valueOption, id), ackActor: ActorRef, ackMsg: AnyRef) =>
      context.setReceiveTimeout(timoutForPersistenceFailure)
      outstandingAckId = id
      outstandingValueOption = valueOption
      persistenceOutstandingAck = true
      replicatorsOutstandingAck = replicasToReplicatorsMap.values.toSet
      retriesDone = 0
      this.ackActor = ackActor
      this.ackMsg   = ackMsg
      this.repMsg   = r
      sendMsgToPersistorAndReplicators()

    case Persisted (key, msgId) => if (msgId==outstandingAckId)
                                   {persistenceOutstandingAck  =  false;   checkReady()}
    case Replicated(key, msgId) => if (msgId==outstandingAckId)
                                   {replicatorsOutstandingAck -= sender;   checkReady()}
    case Replicas (replicas)    =>  replicatorsOutstandingAck &=
                                    replicasToReplicatorsMap.values.toSet; checkReady()


    case ReceiveTimeout =>
      if (retriesDone < retriesForGiveup - 1) {
        retriesDone += 1
        sendMsgToPersistorAndReplicators()
      }
      else ackActor ! OperationFailed(outstandingAckId)
  }
}
```

Akka Actors: KV-Store Assignment - 4

```
class SingleKeyManager2(key: String) extends SubScriptActor { // 44 lines

  var persistorTBD                = true
  var replicatorsTBAck            = Set.empty[ActorRef]
  var valueOption: Option[String] = None
  var tbAckId                     = -1L

  val timoutForPersistenceFailure = 100.milliseconds
  val timoutForPersistenceGiveup  =   1.seconds
  val retriesForGiveup = timoutForPersistenceGiveup / timoutForPersistenceFailure

  def keyIsStored = valueOption != None
  def replicas    = replicasToReplicatorsMap.values.toSet // from parent class

  def script..

    live =  handleReplicateMsg / ..
         || handleReplicasMsg   ...
         ; while(keyIsStored)

    handleReplicateMsg = ~~~

    handleReplicasMsg  = ~~~
}
```

Akka Actors: KV-Store Assignment - 5

```
class SingleKeyManager2(key: String) extends SubScriptActor { // 44 lines
  ~~~
  def script..
    live = ~~~
    handleReplicateMsg   = << Replicate (r@Replicate(key, valueOption, id),
                                         replyActor: ActorRef, ackMsg: AnyRef)
                              => this.tbAckId         = id
                                 this.valueOption     = valueOption
                                 this.replicasTBAck   = replicas
                                 this.persistorTBD    = true
                                 var  replyMsg        = OperationFailed(tbAckId)

                             ==>  ( times(retriesForGiveup);
                                      timeout(timoutForPersistenceFailure)
                                    || ( delegatePersistor & delegateReplicators(r) )
                                      {!replyMsg=ackMsg!}
                                      break_up2
                                  )
                                ; {!replyActor!replyMsg!}
                           >>

     handleReplicasMsg   = ~~~
     delegatePersistor   = ~~~
     delegateReplicators(replicateMsg: Any) = ~~~
}
```

Akka Actors: KV-Store Assignment - 6

```
class SingleKeyManager2(key: String) extends SubScriptActor { // 44 lines
  ~~~
  def script..

    live = ~~~

    handleReplicateMsg = ~~~

    handleReplicasMsg  = <<Replicas(rs) => foreach (r< replicasTBAck-rs)
                                          {self!Replicated(key,tbAckId)} >>

    delegatePersistor  = if (persistorTBD) (
                           {persistor ! Persist(key, valueOption, tbAckId))}
                           << Persisted (key, @tbAckId) => persistorTBD=false >>
                         )

     delegateReplicators(replicateMsg: Any)
                        = for (r <- replicasTBAck)
                        & {r ! replicateMsg}
                          << Replicated(key, @tbAckId) if sender==r
                                          => replicasTBAck -= r >>
}
```

Conclusion

- Easy and efficient programming
- Support in Scalac branch
- Simple implementation: 5000 lines, 50%
- Still much to do and to discover
- Open Source:
  subscript-lang.org
  github.com/AndreVanDelft/scala
- Help is welcome
  Participate!

The End

- Spare Slides next

SubScript Features - 1

"Scripts" – process refinements as class members

- Called like methods from Scala
  - with a ScriptExecutor as extra parameter
- Call other scripts
- Parameters: in, out?, constrained, forcing

Formal	`implicit key(c??: Char) = ...`		
Actual Calls	Output	Constrained	Forcing
Conventional	`key(c?)`	`key(c? if? c.isDigt)`	`key('1')`
No parentheses	`key,c?`	`key,c? if? c.isDigt`	`key,'1'`
Using `implicit`	`c?`	`c? if? c.isDigt`	`'1'`

SubScript Features - 2

ACP Atomic Actions ~ Scala Code {…} start/end

{ … }	Normal
{? … ?}	Unsure
{! … !}	Immediate
{* … *}	New thread
@gui: { … }	GUI thread
@dbThread: { … }	DB thread
@reactor: {. … .}	Event handler
@reactor: {... … ...}	Event handler, permanent
@startTime: { … }	Simulation time + real time
@processor=2: {* … *}	Processor assignment
@priority=2: {* … *}	Priority
@chance=0.5: { … }	Probability

SubScript Features - 3

N-ary operator	Meaning
; ws	Sequence
+	Choice
&	Normal parallel
|	Or-parallel
&&	And-parallel
||	Or-parallel
==>	Network/pipe
/	Disrupt
%/	Interrupt

Unary operator	Meaning
x*	Process launch

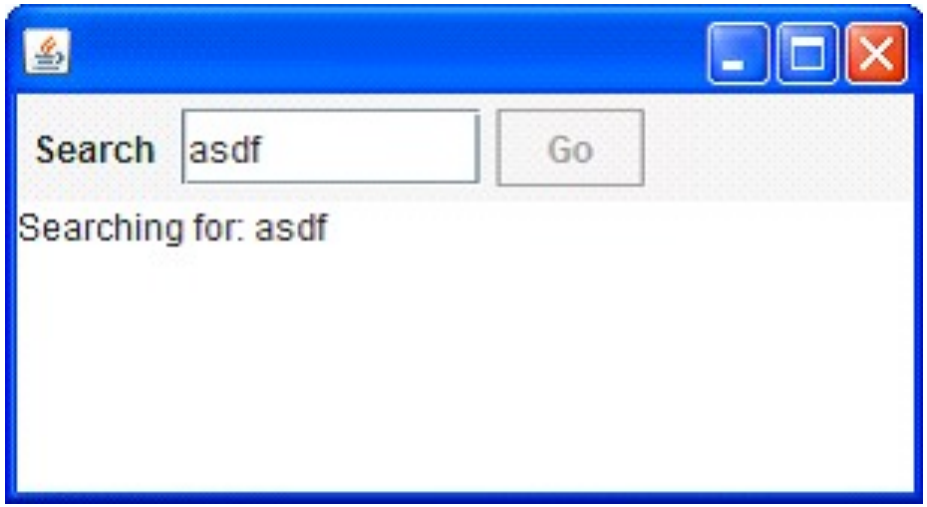
Construct	Meaning
here	Current position
@ … :	Annotation
if-else	
match	
try-catch-	
for	
while	
break	
...	while(true)
..	Both ... and .
.	Optional break
(-), (+),	Neutral: 0, 1-like

SubScript Features - 4

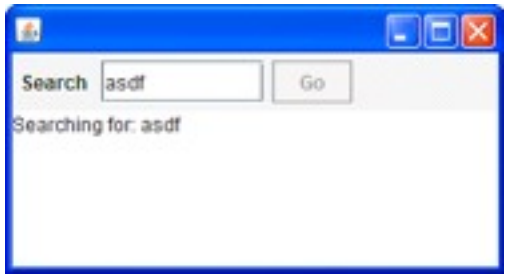
Process Communication

Definitions: Shared Scripts	
`send(i:Int), receive(j??:Int) = {j=i}`	
`send(i:Int), receive(i??: _ ) = {}`	
`ch<-(i:Int),  ch->(i??:Int) = {}`	
`ch<-->(i??:Int) = {}`	
`  <-->(i??:Int) = {}`	
`  <==>(i??:Int) = {}`	
Usage: Multicalls	
`  send(10) & receive(i?)`	Output param
`  send(10) & receive(10)`	Forcing
`  ch<-(10) &  ch->(10)`	Channel
`  <-10  &  ->i?`	Nameless
`  *<-10  ;  ->i?`	Asynchronous send

GUI application - 1

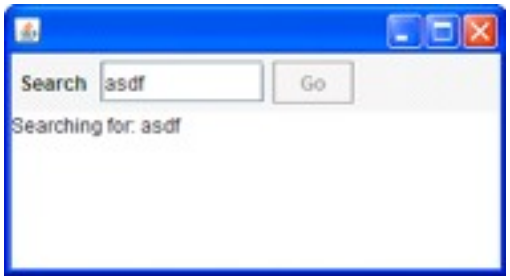


- Input Field
- Search Button
- Searching for…
- Results



GUI application - 2

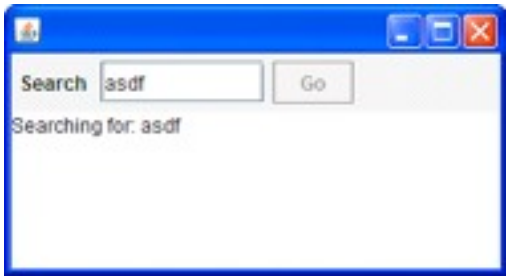
```
val searchButton = new Button("Go”) {
  reactions.+= {
    case ButtonClicked(b) =>
      enabled = false
      outputTA.text = "Starting search...”
      new Thread(new Runnable {
       def run() {
        Thread.sleep(3000)
        SwingUtilities.invokeLater(new Runnable{
          def run() {outputTA.text="Search ready”
                     enabled = true
        }})
      }}).start
  }
}
```



GUI application - 3

```
live =        searchButton
       @gui: {outputTA.text="Starting search.."}
             {* Thread.sleep(3000) *}
       @gui: {outputTA.text="Search ready"}
             ...
```

- Sequence operator: white space and `;`
- `gui`: code executor for `SwingUtilities.InvokeLater`+`InvokeAndWait`
- `{* ... *}`: by executor for `new Thread`

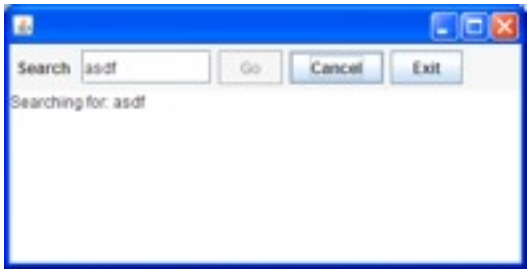


GUI application - 4

```
live                = searchSequence...

searchSequence      = searchCommand
                      showSearchingText
                      searchInDatabase
                      showSearchResults

searchCommand       = searchButton
showSearchingText   = @gui: {outputTA.text = "…"}
showSearchResults   = @gui: {outputTA.text = "…"}
searchInDatabase    = {* Thread.sleep(3000) *}
```

GUI application - 5

- Search: button or Enter key
- Cancel: button or Escape key
- Exit: button or . . . "Are you sure?"…
- Search only allowed when input field not empty
- Progress indication



GUI application - 6

```
live              = searchSequence... || exit

searchCommand     = searchButton + Key.Enter
cancelCommand     = cancelButton + Key.Escape
exitCommand       =   exitButton + windowClosing
exit              =   exitCommand @gui: while(!areYouSure)
cancelSearch      = cancelCommand @gui: showCanceledText

searchSequence    = searchGuard searchCommand;
                    showSearchingText
                    searchInDatabase
                    showSearchResults / cancelSearch

searchGuard       = if(!searchTF.text.isEmpty) . anyEvent(searchTF) ...


searchInDatabase  = {*Thread.sleep(3000)*} || progressMonitor
progressMonitor   = {*Thread.sleep( 250)*}
                    @gui:{searchTF.text+=here.pass} ...
```

Split Scripts - 1

```
header:              do~ s:script ~while~ b: =>Boolean ~end

same as:             do~~while~~end(s:script, b: =>Boolean)


define:  do~ s:script ~while~ b: =>Boolean ~end = s while(b)


usage:   test = do~<  a;b   >~while~ !found ~end
```

Split Scripts - 2

```
progressMonitor = sleep_ms(250) updateStatus ...
                || sleep_ms(5000)
```

```
progressMonitor = during_ms~ 5000
                  ~every_ms~ 250
                  ~do~< updateStatus >~end
```

```
during_ms~ duration:Int
~every_ms~ interval:Int
~do~ task:script ~end = sleep_ms(interval) task...
                      || sleep_ms(duration)
```

Script Result Values - 1

```
expr   = term   .. "+"
term   = factor .. "*"
factor = number + "(" expr ")"
```

```
expr   : expr PLUS term  { $$ = $1 + $3; }
               |  term  { $$ = $1; } ;
term   : term MUL factor { $$ = $1 * $3; }
               | factor { $$ = $1; } ;
factor : LPAR expr RPAR  { $$ = $2; }
               | NUMBER { $$ = $1; };
```

Script Result Values - 2

```
~ tsk:script ~~ f:Unit ~:Int = @onDeactivateWithSuccess{f}: tsk


expr(?r:Int) = {!r=0!}; var t:Int ~<  term(?t)>~~r+=t~  .. "+"
term(?r:Int) = {!r=1!}; var t:Int ~<factor(?t)>~~r*=t~  .. "*"

factor(?n:Int) = ?n + "(" expr,?n ")"


implicit num(??n:Int) = @expNum(_n): {?accept?}
```

Script Result Values - 3

```
~ task: script[Int] ~~ f: Int=>Int ~ : Int
=
    @onDeactivateWithSuccess{$ = f($task)}: task


expr  : Int = {!0!}^; ~< term >~~ $ + _ ~^  .. "+"
term  : Int = {!1!}^; ~<factor>~~ $ * _ ~^  .. "*"

factor: Int = ?$ + "(" expr^ ")"
```

Challenges

- Implementation 50%: compiler, vm, debugger
- Unit tests
- vms for simulations, parallel execution, ...
- New features
  - split scripts
  - process lambdas
  - return values
  - data flow
  - disambiguation
- Documentation, papers, ...

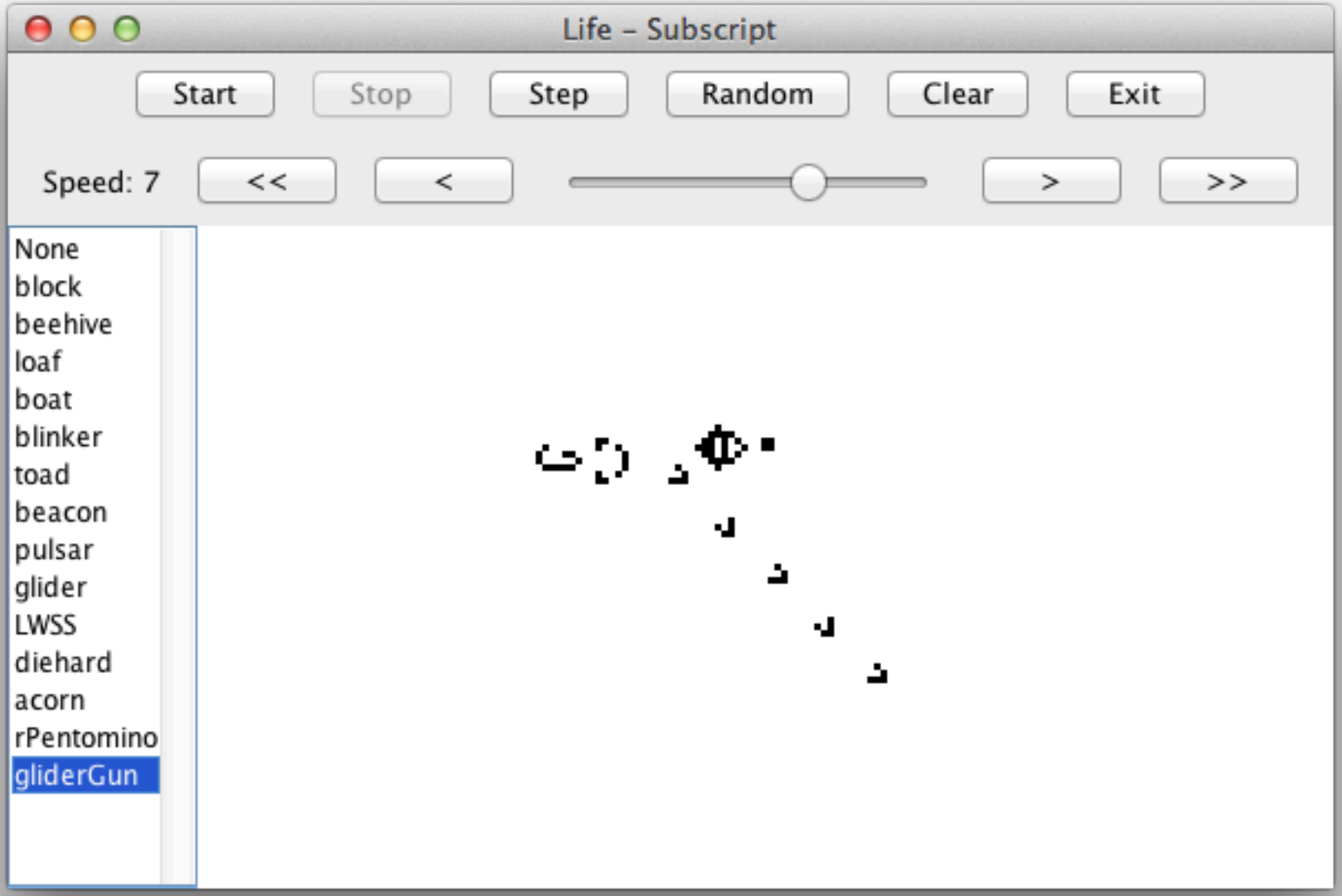
Challenge: Disambiguation

```
  a b  +  a c

..a b  ;  a c
```

```
  a b  ||  a c
```

```
  a b  |+|  a c

..a b  |;|  a c
```

Game of Life - 1



Game of Life - 2

```
  live           = ||  boardControl mouseInput speedControl doExit

 boardControl    = ...; (..singleStep) multiStep || clear || randomize

 doExit          = exitCommand var r=false @gui:{r=areYouSure} while(!r)

randomizeCommand = randomizeButton + 'r'
    clearCommand =     clearButton + 'c'
     stepCommand =      stepButton + ' '
     exitCommand =      exitButton + windowClosing,top
multiStepStartCmd =     startButton + Key.Enter
multiStepStopCmd =      stopButton + Key.Enter

do1Step          = {*board.calculateGeneration*} @gui: {!board.validate!}

randomize        =   randomizeCommand @gui: {!board.doRandomize()!}
clear            =       clearCommand @gui: {!board.doClear      !}
singleStep       =        stepCommand do1Step
 multiStep       = multiStepStartCmd; ...do1Step {*sleep*}
                 / multiStepStopCmd
```

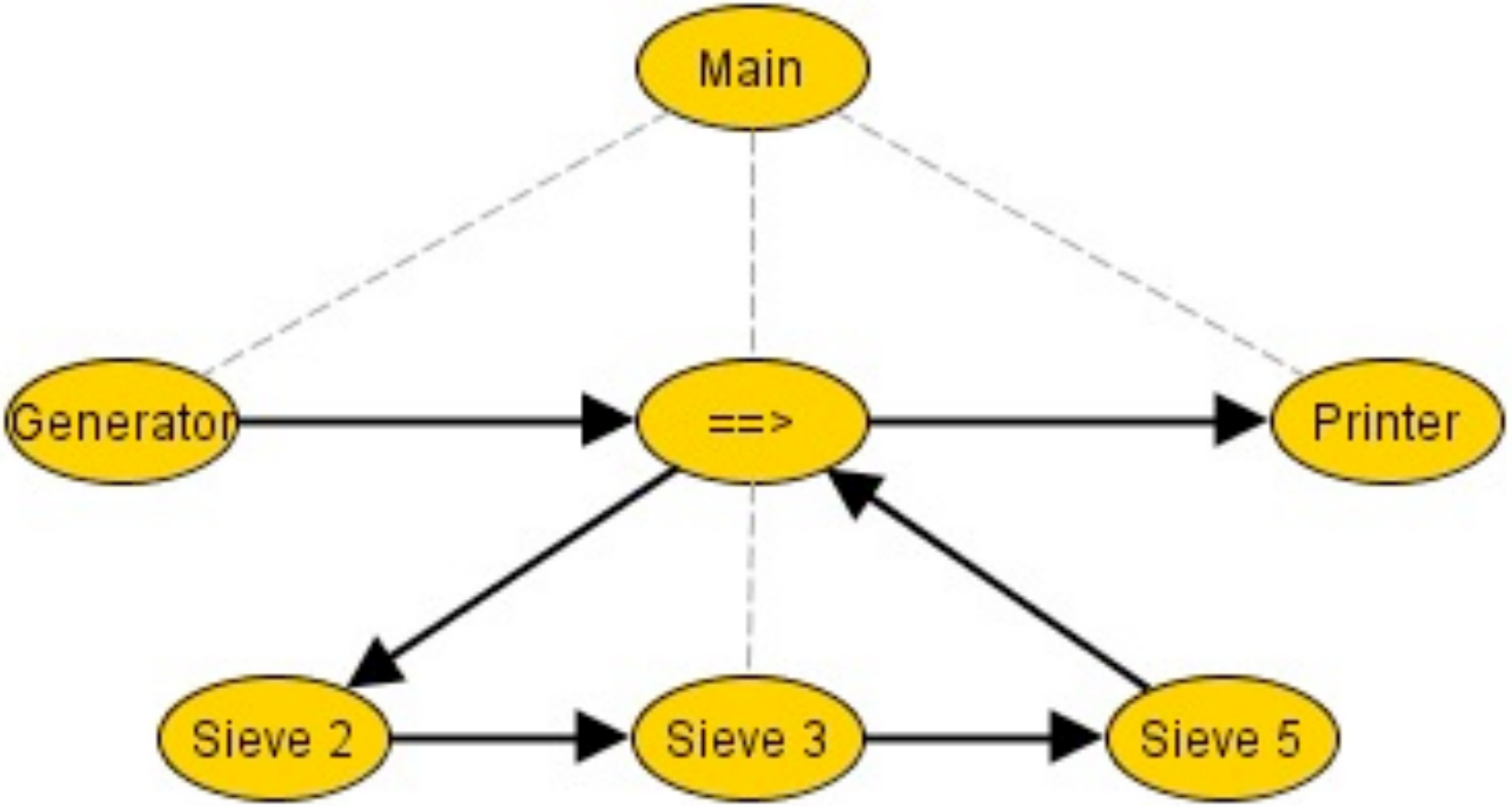
Game of Life - 3

```
speedControl     = ...; speedKeyInput+speedButtonInput+speedSliderInput

setSpeed(s: Int) = @gui: {!setSpeedValue(s)!}

speedKeyInput    = times(10)
                 + val c = chr(pass_up1+'0') key(c)
                   setSpeed(digit2Speed(c))

speedButtonInput = if (speed>minSpeed) speedDec
                 + if (speed<maxSpeed) speedInc

speedDec         = minSpeedButton setSpeed,minSpeed
                 +   slowerButton setSpeed(speed-1)
speedInc         = maxSpeedButton setSpeed,maxSpeed
                 +   fasterButton setSpeed(speed+1)

speedSliderInput = speedSlider setSpeed,speedSlider.value
```

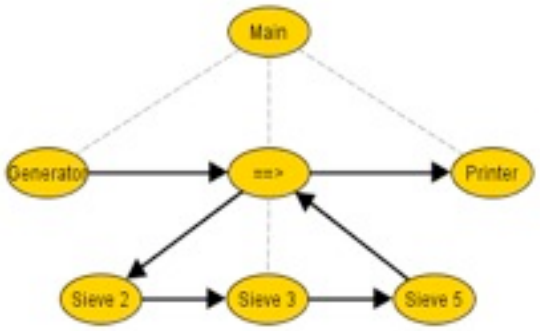
Game of Life - 4

```
mouseInput     = (mouseClickInput & mouseDragInput)
               /  doubleClick
                  (mouseMoveInput / doubleClick {!resetLastMousePos!}); ...

mouseClickInput  = var p:java.awt.Point=null
                 ; var doubleClickTimeout=false
                   mouseSingleClick, board, p?
                   {! resetLastMousePos !}
                   ( {*sleep_ms(220); doubleClickTimeout=true*}
                   / mouseDoubleClick, board, p? )
                   while (!doubleClickTimeout)
                 ; {! handleMouseSingleClick(p) !}
                 ; ...

 mouseMoveInput  = mouseMoves(    board,(e:MouseEvent)=>handleMove(e.point))
 mouseDragInput  = mouseDraggings(board,(e:MouseEvent)=>handleDrag(e.point))
                 / (mouse_Released  {!resetLastMousePos!})
                 ; ...
```

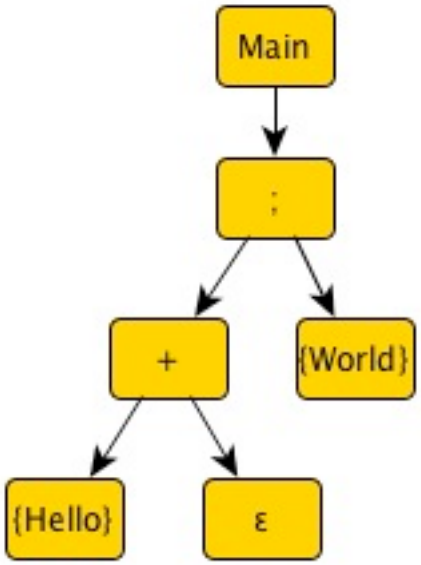
Sieve of Eratosthenes - 1



Sieve of Eratosthenes - 2

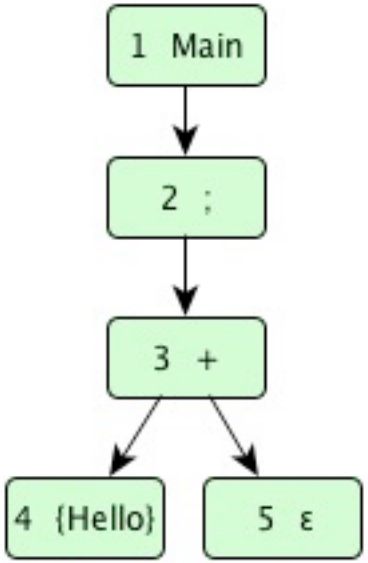


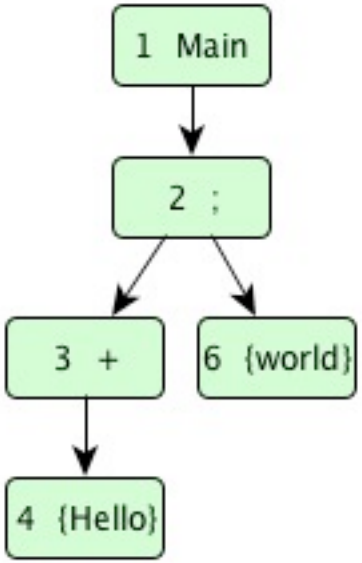

```
main = generator(2,1000000)
                ==> (..==>sieve)
   ==={toPrint}==> printer

generator(s:Int,e:Int) = for(i<-s to e) <=i

sieve           =   =>?p:Int    @toPrint:<=p;
                  ..=>?i:Int if (i%p!=0) <=i

printer         = ..=>?i:Int println,i

<==>(i:Int)     = {}
```

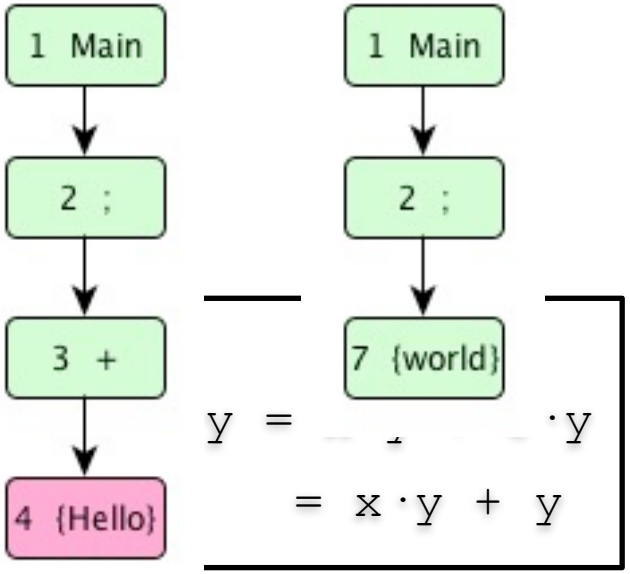


Templates & Call Graphs

```
{Hello}+ε; {World}
```







Experience

- Scriptic: Java based predecessor
- In production since 2010
- Analyse technical documentation
- Input: ODF ~ XML Stream
- Fun to use mixture of grammar and 'normal' code
- Parser expectations to scanner

```
implicit text(??s: String) = @expect(here,  TextToken(_s): {?accept(here)?}
implicit number(??n:  Int) = @expect(here,NumberToken(_n): {?accept(here)?}
```

- 30,000 accepted of 120,000 expected tokens per second

Language Parsing - 1

Low level scripts

```
anyText         = string^
anyLine         = anyText^ endOfLine

someEmptyLines = ..endOfLine
someLines       = {!List[String]()!}^; .. (anyLine==>{! $ :+ _ !}^)
```

Language Parsing - 2

For-usage

```
tableRow(ss: String*) = startRow; for(s<-ss) cell(s); endRow
```

```
oneOf(ss: String*) = for(s<-ss) + s^
```

Language Parsing - 3

If-usage

```
footnoteRef(??n: Int) = "(" ??n ")"


footnote(??n: Int): String = if (fnFormat==NUMBER_DOT) (??n ".")
                               else           (footnoteRef,??n "-")
                           ; line^
                           ; .. (line^ ==> {: $ += "."+_.trim :})
```

Experience - 5

Grammar ambiguity

```
var s: String
var n: Int

startCell ?s endCell  +  startCell ?n endCell
startCell ?s endCell  ||  startCell ?n endCell
startCell ?s endCell |+| startCell ?n endCell
```

```
xmlTag(t: XMLTag), .. = @expect(here, t) {?accept(here)?}
```