State of Scala

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Typesafe and EPFL

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Trajectory

10 years ago

- The plan: Unify functional and object-oriented programming in a practical language.

8 years ago

- First Scala release (experimental, students as subjects)

5 years ago

- Open source system forms around Scala

3 years ago

- Industrial adoption starts, spreads rapidly through internet companies and financial sector.

1 year ago

- First Scala Days conference demonstrates strength of community, demand for industrial support.

#1 Concern: Concurrency and Parallelism

Two motivations:

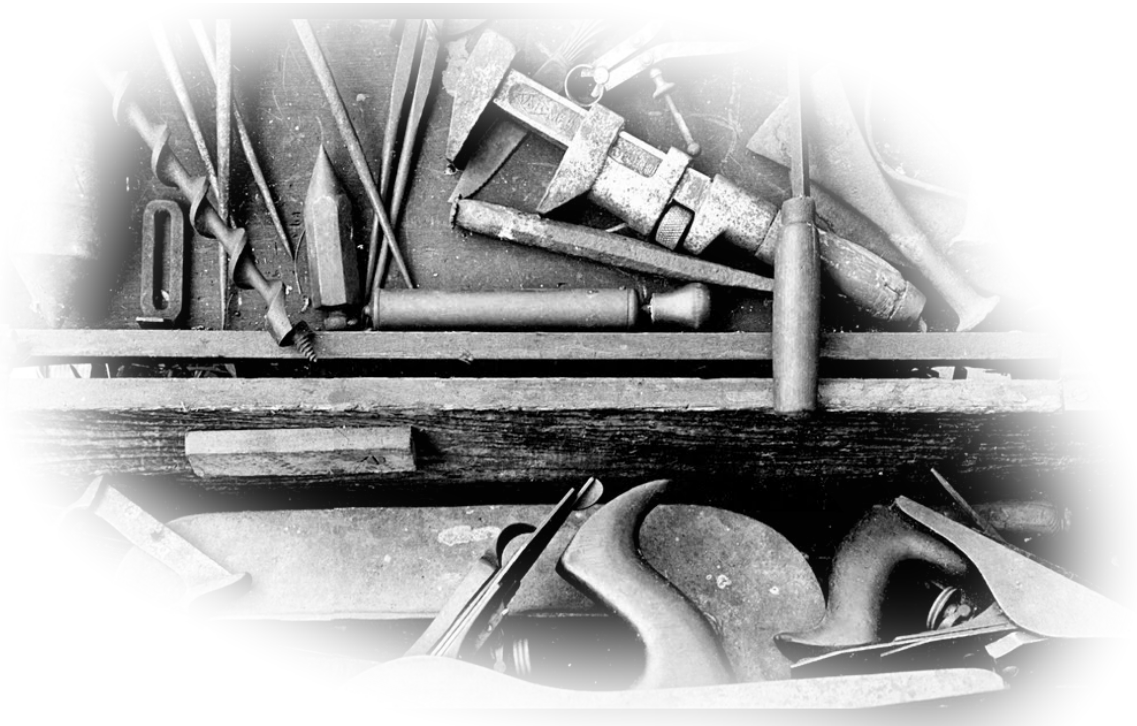
- Make use of multicore/GPU processing power (scale-up)
- Distribute computations over many nodes (scala-out)

Two approaches:

- Explicit: Programmer defines and manages processes
- Implicit: Control of parallelism given to system

- ➢ Implicit is simpler,
- ➢ But explicit is often needed when nodes and connections can fail.

Scala's Toolbox



Different Tools for Different Purposes

Implicit:

Collections → Parallel Collections
Collections → Distributed Collections

Parallel DSLs

Explicit:

Actors
Software transactional memory
Futures

} **Akka**

Scala Collections: Building Interesting Things in Space

- De-emphasize destructive updates
- Focus on *transformers* that map collections to collections
- Have a complete range of *persistent* collections

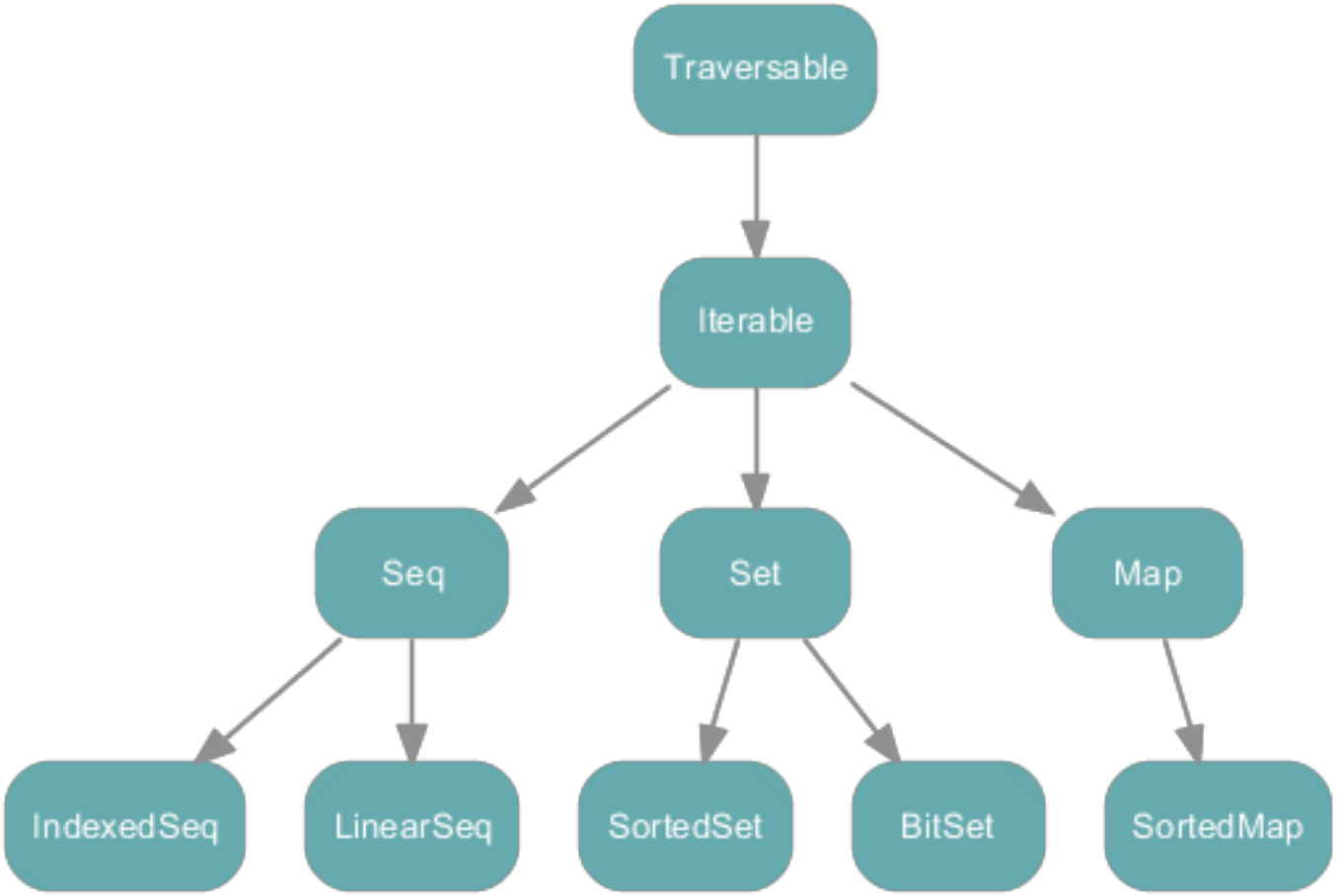
```
scala> val ys = List(1, 2, 3)
ys: List[Int] = List(1, 2, 3)

scala> val xs: Seq[Int] = ys
xs: Seq[Int] = List(1, 2, 3)

scala> xs map (_ + 1)
res0: Seq[Int] = List(2, 3, 4)

scala> ys map (_ + 1)
res1: List[Int] = List(2, 3, 4)
```

Some General Scala Collections



Constructed automatically using *decodify*.

An Example

- Task: Phone keys have mnemonics assigned to them.

```
val mnemonics = Map(
      '2' -> "ABC", '3' -> "DEF", '4' -> "GHI", '5' -> "JKL",
      '6' -> "MNO", '7' -> "PQRS", '8' -> "TUV", '9' -> "WXYZ")
```

- Assume you are given a dictionary `dict` as a list of words. Design a class `Coder` with a method `translate` such that

```
new Coder(dict).translate(phoneNumber)
```

  produces all phrases of words in dict that can serve as mnemonics for the phone number.

- Example: The phone number “7225276257” should have the mnemonic

  `Scala rocks`

  as one element of the list of solution phrases.

Program Example: Phone Mnemonics

- This example was taken from:

  Lutz Prechelt: An Empirical Comparison of Seven Programming Languages. IEEE Computer 33(10): 23-29 (2000)

- Tested with Tcl, Python, Perl, Rexx, Java, C++, C

- Code size medians:
  - 100 loc for scripting languages
  - 200-300 loc for the others

Outline of Class Coder

```
class Coder(words: List[String]) {

  private val mnemonics = Map(
      '2' -> "ABC", '3' -> "DEF", '4' -> "GHI", '5' -> "JKL",
      '6' -> "MNO", '7' -> "PQRS", '8' -> "TUV", '9' -> "WXYZ")

  /** Invert the mnemonics map to give a map from chars 'A' ... 'Z' to '2' ... '9' */
  private val charCode: Map[Char, Char] = ??

  /** Maps a word to the digit string it can represent, e.g. “Java” -> “5282” */
  private def wordCode(word: String): String = ??

  /** A map from digit strings to the words that represent them,
    * e,g. “5282” -> Set(“Java”, “Kata”, “Lava”, ...) */
  private val wordsForNum: Map[String, Set[String]] = ??

  /** Return all ways to encode a number as a list of words */
  def encode(number: String): Set[List[String]] = ??

  /** Maps a number to a list of all word phrases that can represent it */
  def translate(number: String): Set[String] = encode(number) map (_ mkString " ")
}
```

Class Coder (1)

```
class Coder(words: List[String]) {

  private val mnemonics = Map(
      '2' -> "ABC", '3' -> "DEF", '4' -> "GHI", '5' -> "JKL",
      '6' -> "MNO", '7' -> "PQRS", '8' -> "TUV", '9' -> "WXYZ")

  /** Invert the mnemonics map to give a map from chars 'A' ... 'Z' to '2' ... '9' */
  private val charCode: Map[Char, Char] =


  /** Maps a word to the digit string it can represent */
  private def wordCode(word: String): String = ??

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Class Coder (1)

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      '6' -> "MNO", '7' -> "PQRS", '8' -> "TUV", '9' -> "WXYZ")

  /** Invert the mnemonics map to give a map from chars 'A' ... 'Z' to '2' ... '9' */
  private val charCode: Map[Char, Char] =
    for ((digit, str) <- mnemonics; ltr <- str) yield (ltr -> digit)

  /** Maps a word to the digit string it can represent */
  private def wordCode(word: String): String = ??

  /** A map from digit strings to the words that represent them */
  private val wordsForNum: Map[String, List[String]] = ??

  /** Return all ways to encode a number as a list of words */
  def encode(number: String): Set[List[String]] = ??

  /** Maps a number to a list of all word phrases that can represent it */
  def translate(number: String): Set[String] = encode(number) map (_ mkString " ")
}
```

Class Coder (2)

```
class Coder(words: List[String]) {

  private val mnemonics = Map(
      '2' -> "ABC", '3' -> "DEF", '4' -> "GHI", '5' -> "JKL",
      '6' -> "MNO", '7' -> "PQRS", '8' -> "TUV", '9' -> "WXYZ")

  /** Invert the mnemonics map to give a map from chars 'A' ... 'Z' to '2' ... '9' */
  private val charCode: Map[Char, Char] =
    for ((digit, str) <- m; letter <- str) yield (letter -> digit)

  /** Maps a word to the digit string it can represent, e.g. “Java” -> “5282” */
  private def wordCode(word: String): String =



  /** A map from digit strings to the words that represent them */
  private val wordsForNum: Map[String, Set[String]] = ??

  /** Return all ways to encode a number as a list of words */
  def encode(number: String): Set[List[String]] = ??

  /** Maps a number to a list of all word phrases that can represent it */
  def translate(number: String): Set[String] = encode(number) map (_ mkString " ")
}
```

Class Coder (2)

```
class Coder(words: List[String]) {

  private val mnemonics = Map(
      '2' -> "ABC", '3' -> "DEF", '4' -> "GHI", '5' -> "JKL",
      '6' -> "MNO", '7' -> "PQRS", '8' -> "TUV", '9' -> "WXYZ")

  /** Invert the mnemonics map to give a map from chars 'A' ... 'Z' to '2' ... '9' */
  private val charCode: Map[Char, Char] =
    for ((digit, str) <- m; letter <- str) yield (letter -> digit)

  /** Maps a word to the digit string it can represent, e.g. “Java” -> “5282” */
  private def wordCode(word: String): String =
    word.toUpperCase map charCode

  /** A map from digit strings to the words that represent them */
  private val wordsForNum: Map[String, Set[String]] = ??

  /** Return all ways to encode a number as a list of words */
  def encode(number: String): Set[List[String]] = ??

  /** Maps a number to a list of all word phrases that can represent it */
  def translate(number: String): Set[String] = encode(number) map (_ mkString " ")
}
```

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Class Coder (3)

```
class Coder(words: List[String]) {

  private val mnemonics = Map(
      '2' -> "ABC", '3' -> "DEF", '4' -> "GHI", '5' -> "JKL",
      '6' -> "MNO", '7' -> "PQRS", '8' -> "TUV", '9' -> "WXYZ")

  /** Invert the mnemonics map to give a map from chars 'A' ... 'Z' to '2' ... '9' */
  private val charCode: Map[Char, Char] =
    for ((digit, str) <- m; letter <- str) yield (letter -> digit)

  /** Maps a word to the digit string it can represent */
  private def wordCode(word: String): String =
    word.toUpperCase map charCode

  /** A map from digit strings to the words that represent them,
    * e,g. "5282" -> Set("Java", "Kata", "Lava", ...) */
  private val wordsForNum: Map[String, List[String]] =




  /** Return all ways to encode a number as a list of words */
  def encode(number: String): Set[List[String]] = ??

  /** Maps a number to a list of all word phrases that can represent it */
  def translate(number: String): Set[String] = encode(number) map (_ mkString " ")
}
```

Class Coder (3)

```
class Coder(words: List[String]) {

  private val mnemonics = Map(
      '2' -> "ABC", '3' -> "DEF", '4' -> "GHI", '5' -> "JKL",
      '6' -> "MNO", '7' -> "PQRS", '8' -> "TUV", '9' -> "WXYZ")

  /** Invert the mnemonics map to give a map from chars 'A' ... 'Z' to '2' ... '9' */
  private val charCode: Map[Char, Char] =
    for ((digit, str) <- m; letter <- str) yield (letter -> digit)

  /** Maps a word to the digit string it can represent */
  private def wordCode(word: String): String =
    word.toUpperCase map charCode

  /** A map from digit strings to the words that represent them,
    * e,g. "5282" -> Set("Java", "Kata", "Lava", ...) */
  private val wordsForNum: Map[String, List[String]] =
     (words groupBy wordCode) withDefaultValue List()

  /** Return all ways to encode a number as a list of words */
  def encode(number: String): Set[List[String]] = ??

  /** Maps a number to a list of all word phrases that can represent it */
  def translate(number: String): Set[String] = encode(number) map (_ mkString " ")
}
```

Class Coder (4)

```
class Coder(words: List[String]) { ...

  /** Return all ways to encode a number as a list of words */
   def encode(number: String): Set[List[String]] =









  /** Maps a number to a list of all word phrases that can represent it */
  def translate(number: String): Set[String] = encode(number) map (_ mkString " ")
}
```

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Class Coder (4)

```
class Coder(words: List[String]) { ...

  /** Return all ways to encode a number as a list of words */
  def encode(number: String): Set[List[String]] =
    if (number.isEmpty)
      Set(List())

  /** Maps a number to a list of all word phrases that can represent it */
  def translate(number: String): Set[String] = encode(number) map (_ mkString " ")
}
```

Class Coder (4)

```
class Coder(words: List[String]) { ...

  /** Return all ways to encode a number as a list of words */
  def encode(number: String): Set[List[String]] =
    if (number.isEmpty)
      Set(List())
    else {
      for {
        splitPoint <- 1 to number.length
```

```
  /** Maps a number to a list of all word phrases that can represent it */
  def translate(number: String): Set[String] = encode(number) map (_ mkString " ")
}
```

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Class Coder (4)

```
class Coder(words: List[String]) { ...

  /** Return all ways to encode a number as a list of words */
  def encode(number: String): Set[List[String]] =
    if (number.isEmpty)
      Set(List())
    else {
      for {
        splitPoint <- 1 to number.length
        word <- wordsForNum(number take splitPoint)




  /** Maps a number to a list of all word phrases that can represent it */
  def translate(number: String): Set[String] = encode(number) map (_ mkString " ")
}
```

Class Coder (4)

```
class Coder(words: List[String]) { ...

  /** Return all ways to encode a number as a list of words */
  def encode(number: String): Set[List[String]] =
    if (number.isEmpty)
      Set(List())
    else {
      for {
        splitPoint <- 1 to number.length
    word <- wordsForNum(number take splitPoint)
        rest <- encode(number drop splitPoint)
      } yield word :: rest
    }.toSet

  /** Maps a number to a list of all word phrases that can represent it */
  def translate(number: String): Set[String] = encode(number) map (_ mkString " ")
}
```

In Summary

- In the original experiment:
  - Scripting language programs were shorter and often even faster than Java/C/C++ because their developers tended to use standard collections.
- In Scala's solution:
  - Obtained a further 5x reduction in size because of the systematic use of *functional* collections.
- Scala's collection's are also easily upgradable to parallel.

Think collection transformers, not CRUD!

A Solution in Java

By Josh Bloch, author of Java collections

PhoneWordGenerator.java

```
import java.util.*;
import java.io.*;

/**
 * Translate phone numbers to word-sequences that map to the number
 * according to the standard mapping on the keypad (or dial).
 *
 * @author Josh Bloch
 */

public class PhoneWordGenerator {
    /** Map from digit-sequences to the word(s) they map to, e.g. "5278" -> ["kart", "last
"] */
    private final Map<String, List<String>> wordsForNumber = new HashMap<String, List<Stri
ng>>();

    /** Creates a phone word generator for the specified dictionary file */
    public PhoneWordGenerator(String dictFileName) throws IOException {
        // Invert lettersForDigit mapping
        String[] lettersForDigit = { "","","abc","def","ghi","jkl","mno","pqrs","tuv","wxy
z" };
        char[] digitForLetter = new char[26];
        for (int digit = 0; digit < 10; digit++) {
            String letters = lettersForDigit[digit];
            for(int i = 0; i < letters.length(); i++)
                digitForLetter[letters.charAt(i) - 'a'] = (char) (digit + '0');
        }

        // Process dictionary into a map from digit-sequence to the word(s) it maps to
        BufferedReader br = new BufferedReader(new FileReader(dictFileName));
        String word = null;
        try {
            while ((word = br.readLine()) != null) {
                char[] digitSeq = word.toCharArray();  // Intially contains letter sequenc
e
                for (int i = 0; i < digitSeq.length; i++)
                    digitSeq[i] = digitForLetter[digitSeq[i] - 'a'];  // Translate letter
to digit
                String number = new String(digitSeq);

                List<String> words = wordsForNumber.get(number);
                if (words == null)
                    wordsForNumber.put(number, words = new ArrayList<String>());
                words.add(word);
            }
        } catch (ArrayIndexOutOfBoundsException e) {
            throw new IllegalArgumentException("Dictionary contains bogus word: " + word);
        } finally {
            br.close();
        }
    }

    /** Returns a shared instance with the standard English dictionary. Initialized on fir
st use. */
    synchronized public static PhoneWordGenerator getInstance() throws IOException {
        return pwg != null ? pwg : (pwg = new PhoneWordGenerator("WORD.LST"));
    }

    private static PhoneWordGenerator pwg;

    /** Returns a list of the sentences represented by the specified number */
    public List<String> phoneWords(String number) {
        return sentences(number.toCharArray(), 0);
    }

    /** Returns a list of sentences represented by digits[start : digits.length) */
    private List<String> sentences(char[] digits, int start) {
        // Start with any single words represented by entire digit sequence
        List<String> result = new ArrayList<String>(words(digits, start, digits.length - s
tart));

        // Then add any "sentences" of consisting of two or more words
        for (int firstSpace = start + 1; firstSpace < digits.length; firstSpace++)
            result.addAll(cartesianProduct(words(digits, start, firstSpace - start),
                                           sentences(digits, firstSpace)));
        return result;
    }

    /** Returns a list of single words represented by digits[offset : offset + len) */
    private List<String> words(char[] digits, int offset, int len) {
        List<String> result = wordsForNumber.get(new String(digits, offset, len));
        return result != null ? result : Collections.<String>emptyList();
    }

    /** Returns all sentences consisting of a prefix followed by a suffix */
    private static List<String> cartesianProduct(List<String> prefixes, List<String> suffi
xes) {
        List<String> result = new ArrayList<String>();
        for (String prefix : prefixes)
            for (String suffix : suffixes)
                result.add(prefix + " " + suffix);
        return result;
    }

    public static void main(String[] args) throws IOException {
        PhoneWordGenerator pwg = PhoneWordGenerator.getInstance();
        Console console = System.console();
        while (true) {
            System.out.print("Phone number: ");
            System.out.println(pwg.phoneWords(console.readLine()));
        }
    }
}
```

--:**- PhoneWordGenerator.java Top L6 (Java/l Abbrev)----------

--:**- PhoneWordGenerator.java Bot L48 (Java/l Abbrev)----------

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Going Parallel

- In Scala 2.9, collections support parallel operations.
- Two new methods:

  `c.par` returns parallel version of collection `c`

  `c.seq` returns sequential version of collection `c`

- The right tool for addressing the PPP (popular parallel programming) challenge.
- I expect this to be the cornerstone for making use of multicores for the rest of us.

Parallel Coder

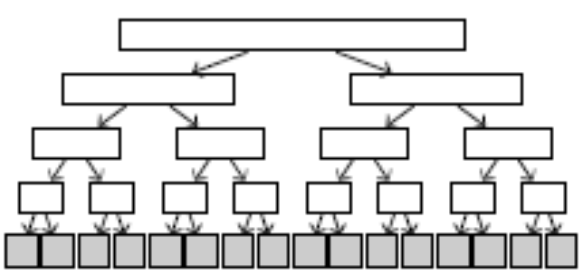
a parallel collection

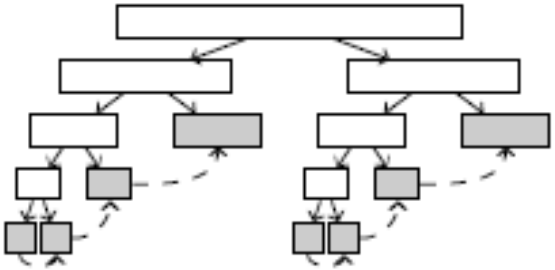
```
class Coder(words: ParVector[String]) {

  private val mnemonics = Map(
      '2' -> "ABC", '3' -> "DEF", '4' -> "GHI", '5' -> "JKL",
      '6' -> "MNO", '7' -> "PQRS", '8' -> "TUV", '9' -> "WXYZ")

  /** Invert the mnemonics map to give a map from chars 'A' ... 'Z' to '2' ... '9' */
  private val charCode: Map[Char, Char] =
    for ((digit, str) <- m; letter <- str) yield (letter -> digit)

  /** Maps a word to the digit string it can represent */
  private def wordCode(word: String): String = word.toUpperCase map charCode

  /** A map from digit strings to the words that represent them */
  private val wordsForNum: Map[String, List[String]] = words groupBy wordCode

  /** Return all ways to encode a number as a list of words */
  def encode(number: String): Set[List[String]] =
    if (number.isEmpty) Set(List())
    else {
      for {
        splitPoint <- (1 to number.length).par
        word <- wordsForNum(number take splitPoint)
        rest <- encode(number drop splitPoint)
      } yield word :: rest
    }.toSet
```

mapping sequential collection to parallel

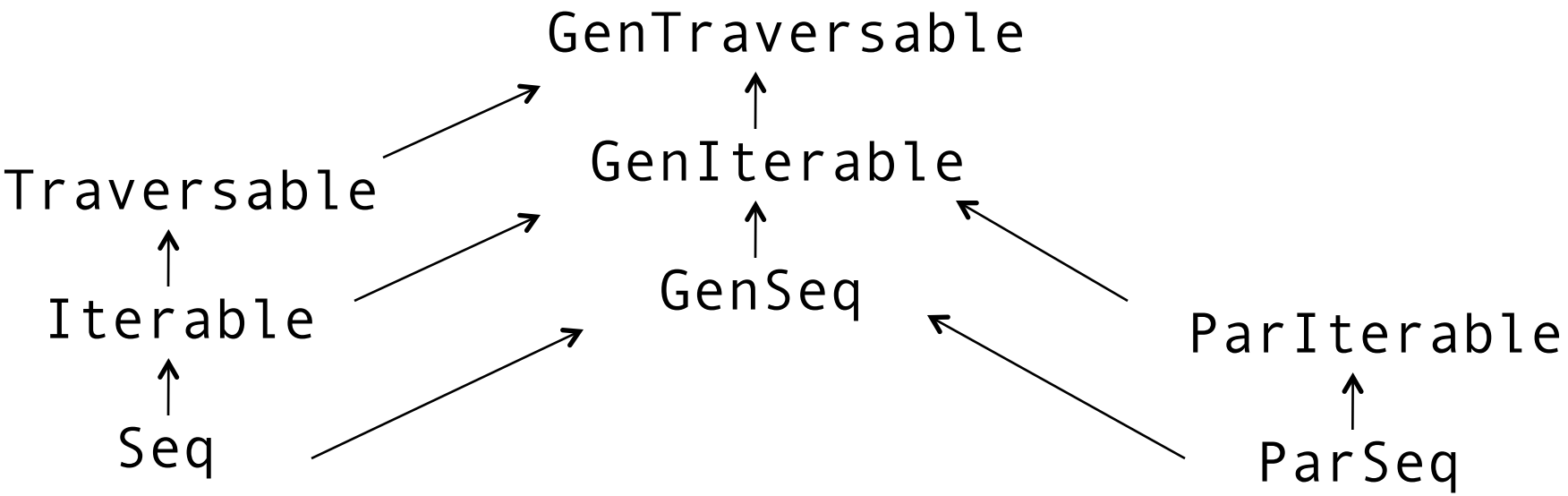
Parallel Collections

- Split work by number of Processors
- Each Thread has a work queue that is split exponentially. Largest on end of queue
- Granularity balance against scheduling overhead
- On completion threads “work steals” from end of other thread queues





General Collection Hierarchy



Going Distributed

- Can we get the power of parallel collections to work on 10’000s of computers?
- Hot technologies: MapReduce (Google’s and Hadoop)
- But not everything is easy to fit into that mold
- Sometimes 100’s of map-reduce steps are needed.
- Distributed collections retain most operations, provide a powerful frontend for MapReduce computations.
- Scala’s uniform collection model is designed to also accommodate parallel and distributed.

The Future

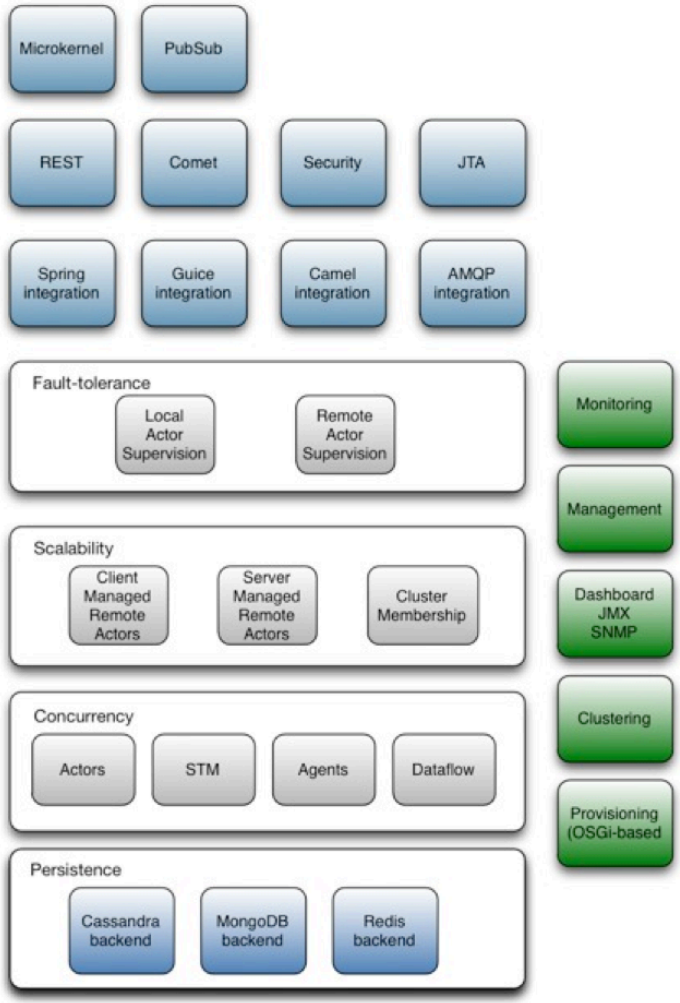
Scala's persistent collections are

- easy to use: *few steps to do the job*
- concise: *one word replaces a whole loop*
- safe: *type checker is really good at catching errors*
- fast: *collection ops are tuned, can be parallelized*
- scalable: *one vocabulary to work on all kinds of collections: sequential, parallel, or distributed.*

I see them play a rapidly increasing role in software development.

Akka: Event-driven Middleware in Scala

- Unified programming model for:
  - **scaling up** to many cores
  - **scaling out** to many nodes
  - fault-tolerance
- Actors:
  - lightweight (run millions on a single node)
  - send and receive messages async
  - location transparent
- Transparent and adaptive:
  - load-balancing and routing
  - replication and fail-over
  - elasticity: grow/shrink dynamically
- Decouples app logic from low-level mechanisms



Akka vs scala.actors

Akka:

+ Best performance
+ Scalable to clusters and clouds
+ Best safety through encapsulation

Scala Actors:

+ Simple to get started
+ Good integration with threads
+ Blocking as well as non-blocking receives
− Erlang-inherited mailbox model can lead to inefficient code

Over the next releases we plan to merge the two libraries.

Other New Developments

- Scala-based reflection
- Type Dynamic
- Effects in an optional pluggable type system (?)

- Libraries:
  - I/O, including event-based
  - STM
  - Reactive programming, GUI

- Most effort will go in tools
  - Eclipse IDE
  - REPL
  - SBT (simple build tool)
  - Type debugger

Going further

But how do we keep a bunch of Fermi's happy?

- How to find and deal with 10000+ threads in an application?
- Parallel collections and actors are necessary but not sufficient for this.

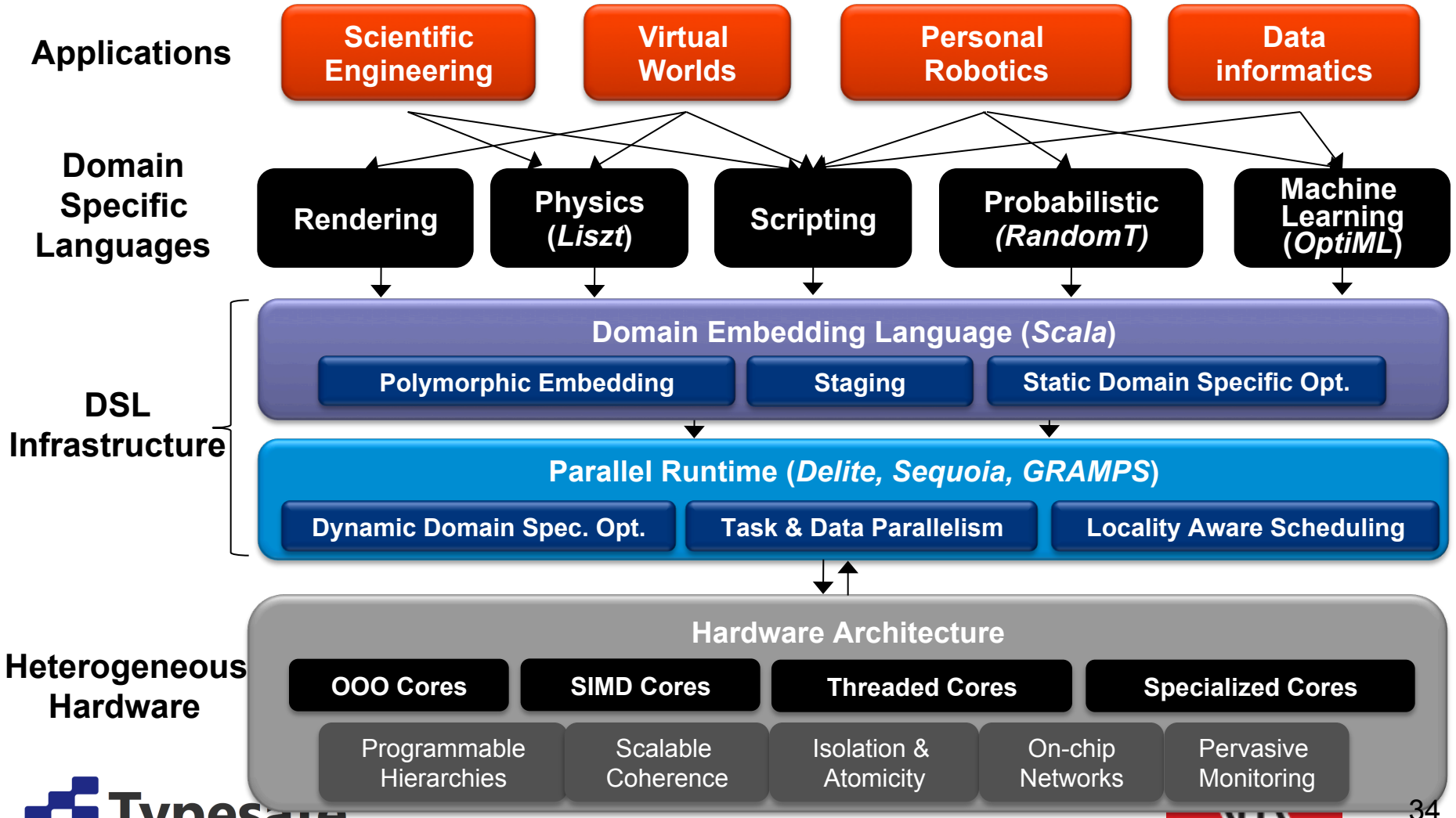
Our bet for the mid term future: parallel embedded DSLs.

- Find parallelism in domains: physics simulation, machine learning, statistics, ...

Joint work with Kunle Olukuton, Pat Hanrahan @ Stanford.

EPFL side funded by ERC.

EPFL / Stanford Research



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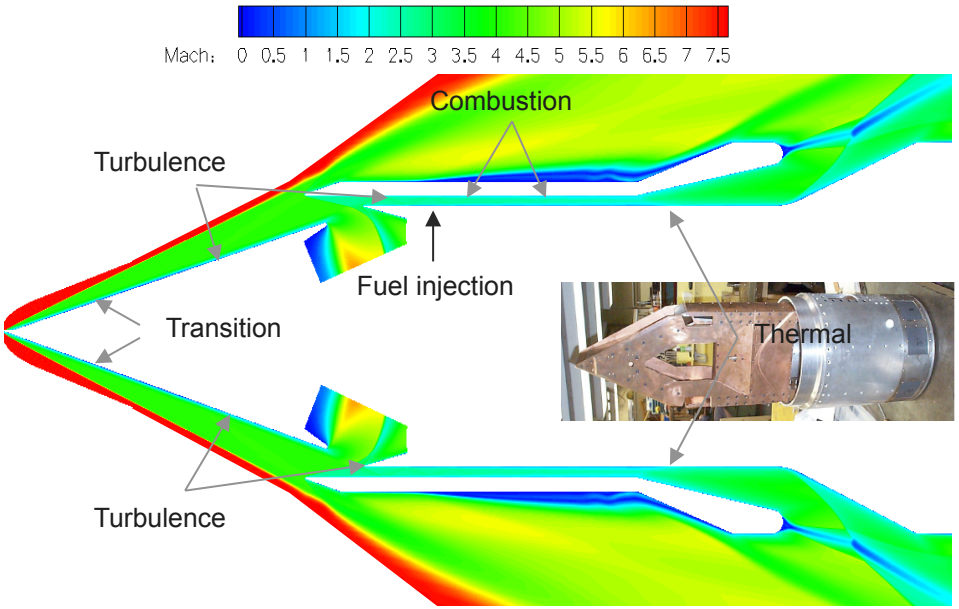
Example: Liszt - A DSL for Physics Simulation

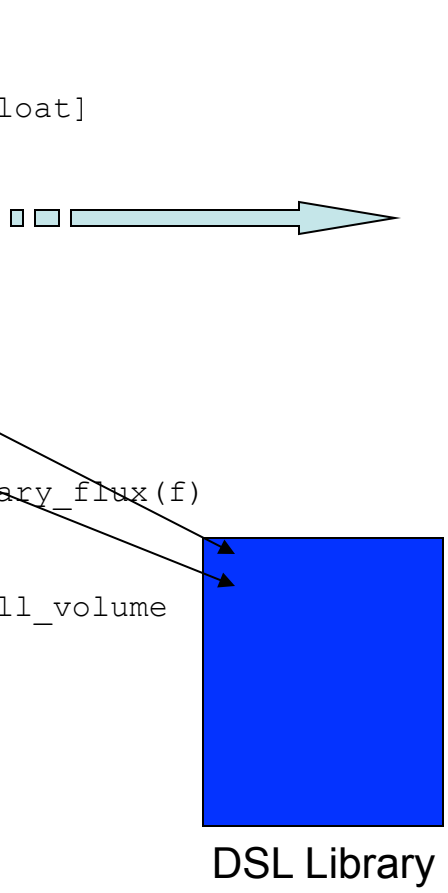


- Mesh-based
- Numeric Simulation
- Huge domains
  - millions of cells
- Example: Unstructured Reynolds-averaged Navier Stokes (RANS) solver

Liszt as Virtualized Scala

```
val // calculating scalar convection (Liszt)

val Flux = new Field[Cell,Float]
val Phi = new Field[Cell,Float]
val cell_volume = new Field[Cell,Float]
val deltat = .001
...
untilconverged {
  for(f <- interior_faces) {
    val flux = calc_flux(f)
    Flux(inside(f)) -= flux
    Flux(outside(f)) += flux
  }
  for(f <- inlet_faces) {
    Flux(outside(f)) += calc_boundary_flux(f)
  }
  for(c <- cells(mesh)) {
    Phi(c) += deltat * Flux(c) /cell_volume
    (c)
  }
  for(f <- faces(mesh))
    Flux(f) = 0.f
}
```



Typesafe

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Other Developments

- DelayedInit
- Dynamic
- Tools
- Reflection
- STM
- @specialized
- Slick
- scala.reflect
- scala.react
- Scala.NET
- Scala.IO (?)
- Effects (?)
- Javascript (?)

Scala 2.9 also introduces two new "magic" traits:

`DelayedInit` and
`Dynamic`

A lot work has been done on the tools side:

Scala IDE for Eclipse 2.0,
SBT 0.10,
enhanced REPL,
Migration Manager Diagnostics (MiMaLib)

Planned Work

DelayedInit

Dynamic

Tools

Reflection

STM

@specialized

Slick

scala.reflect

scala.react

Scala.NET

Scala.IO (?)

Effects (?)

Javascript (?)

Over the next releases, we plan to introduce:

- Scala STM, a standard STM API,
- Enhanced support for @specialized,
- Slick, A common framework for connecting with databases and distributed collections.
- Scala.reflect, a Scala-centric reflection library.
- Scala.react, a reactive programming framework.
- An updated Scala.NET

We are also exploring:

- Adding Scala.IO to the standard distibution
- An effect system for Scala
- A Scala to Javascript translator

DelayedInit and App

DelayedInit
Dynamic
Tools
Reflection
STM
@specialized
Slick
scala.reflect
scala.react
Scala.NET
Scala.IO (?)
Effects (?)
Javascript (?)

Trait Application is convenient, but has hidden problems:

```
object First extends Application {
  println("hi there!)
}
```

Body is executed as part of the object initializer.

`main` method inherited from `Application` is empty.

Body is neither optimized nor threading-friendly.

Solution: Replace `Application` with `App`.

DelayedInit and App

- DelayedInit
- Dynamic
- Tools
- Reflection
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- Effects (?)
- Javascript (?)

Trait App solves these problems:

```
object First extends App {
  println("hi there!)
}
```

Body is now stored in a buffer, executed by `main` method.

Here's an outline of this trait.

```
trait App extends DelayedInit {
  def main(args: Array[String]) =
    for (code <- inits) code()
}
```

Conclusion

Scala has the right "genes" to scale into parallel + distributed computing:

- Strong, practical foundation: JVM
- Functional programming reduces liabilities
- Library-centric approach makes for building tailored solutions.

Makes it possible to write:

- High-level, easy to use libraries (*e.g.*, collections)
- Safer concurrency concepts (*e.g.*, actors)
- Parallel DSLs (*e.g.*, EPFL/Stanford project)

Thank You

scala-lang.org

typesafe.com