The Seductions of Scala - Applications

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Tuesday, September 24, 13

The online version contains more material. You can also find this talk and the code used for many of the examples at github.com/deanwampler/Presentations/tree/master/SeductionsOfScala

Let's examine two popular Scala toolkits used to implement real-world applications.

First reason, we need the benefits of FP.

- Akka: Actors for highly-concurrent applications.
- Scalding: Big data the functional way.

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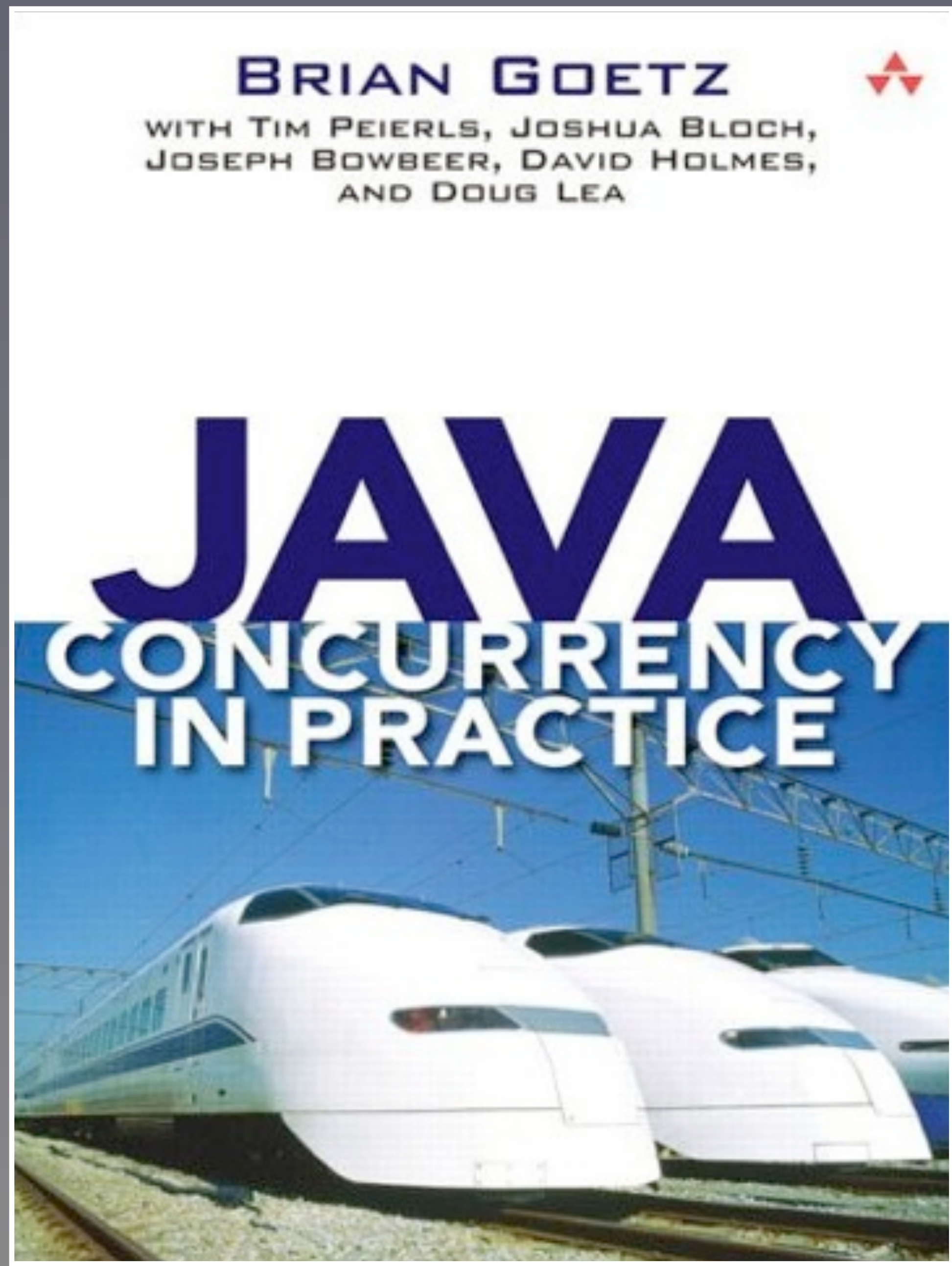
FP is going mainstream because it is the best way to write robust concurrent software. Here’s an example…

When you share mutable state...

Hic sunt dracones
(Here be dragons)



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It's very hard to do multithreaded programming robustly. We need higher levels of abstraction, like Actors.

Actor Model

- Message passing between autonomous actors.
- No shared mutable state.

Actor Model

- First developed in the 70's by Hewitt, Agha, Hoare, etc.
- Made "famous" by Erlang.
  - Scala's Actors patterned after Erlang's.

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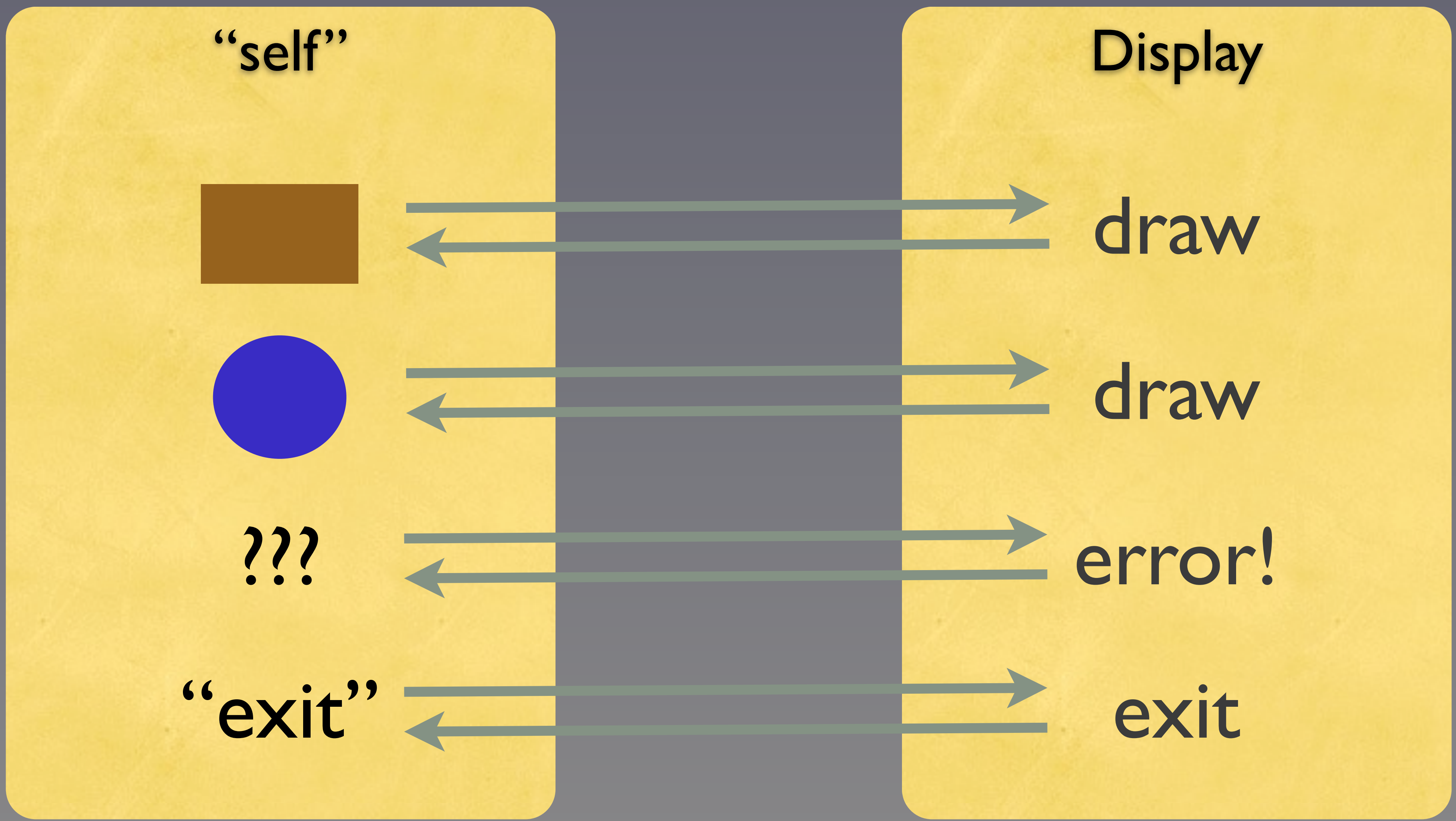
The actor model is not new!!

2 Actors:



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Our example. An actor for drawing geometric shapes and another actor that drives it.

```scala
package shapes

case class Point(
 x: Double, y: Double)

abstract class Shape {
 def draw()
}
```

abstract draw method

Hierarchy of geometric shapes

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"Case" classes for 2-dim. points and a hierarchy of shapes. Note the abstract draw method in Shape. The "case" keyword makes the arguments "vals" by default, adds factory, equals, etc. methods. Great for "structural" objects.
(Case classes automatically get generated equals, hashCode, toString, so-called "apply" factory methods - so you don't need "new" - and so-called "unapply" methods used for pattern matching.)

NOTE: The full source for this example is at https://github.com/deanwampler/Presentations/tree/master/SeductionsOfScala/code-examples/actor.

```scala
case class Circle(
 center:Point, radius:Double)
    extends Shape {
 def draw() = …
}

case class Rectangle(
 ll:Point, h:Double, w:Double)
    extends Shape {
 def draw() = …
}
```

concrete draw methods

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Case classes for 2-dim. points and a hierarchy of shapes. Note the abstract draw method in Shape.
For our example, the draw methods will just do "println("drawing: "+this.toString)".

```scala
package shapes
import akka.actor.Actor

class Drawer extends Actor {
  def receive = {
    ...
  }
}
```

Use the Akka Actor library

Actor

receive and handle each message

Actor for drawing shapes

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An actor that waits for messages containing shapes to draw. Imagine this is the window manager on your computer. It loops indefinitely, blocking until a new message is received...

Note: This example uses the Akka Frameworks Actor library (see http://akka.io), which has now replaced Scala's original actors library. So, some of the basic actor classes are part of Scala's library, but we'll use the full Akka distibution.

Receive method

```
receive = {
 case s:Shape =>
   print("-> "); s.draw()
   sender ! ("Shape drawn.")
 case "exit" =>
   println("-> exiting...")
   sender ! ("good bye!")
 case x =>           // default
   println("-> Error: " + x)
   sender ! ("Unknown: " + x)
}
```


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"Receive" blocks until a message is received. Then it does a pattern match on the message. In this case, looking for a Shape object, the "exit" message, or an unexpected object, handled with the last case, the default.

```
receive = {
  case s:Shape =>
    print("-> "); s.draw()
    sender ! ("Shape drawn.")
  case "exit" =>
    println("-> exiting...")
    sender ! ("good bye!")
  case x =>           // default
    println("-> Error: " + x)
    sender ! ("Unknown: " + x)
}
```

pattern matching

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Each pattern is tested and the first match “wins”. The messages we expect are a Shape object, the “exit” string or anything else. Hence, the last “case” is a “default” that catches anything, we we treat as an unexpected error.

```
receive = {
  case s:Shape =>
    print("-> "); s.draw()
    sender ! ("Shape drawn.")
  case "exit" =>
    println("-> exiting...")
    sender ! ("good bye!")
  case x =>                    // default
    println("-> Error: " + x)
    sender ! ("Unknown: " + x)
}
```

draw shape & send reply

done

unrecognized message

sender ! sends a reply

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After handling each message, a reply is sent to the sender, using “self” to get the handle to our actor “nature”.

```scala
package shapes
import akka.actor.Actor
class Drawer extends Actor {
 receive = {
  case s:Shape =>
    print("-> "); s.draw()
    sender ! ("Shape drawn.")
  case "exit" =>
    println("-> exiting...")
    sender ! ("good bye!")
  case x =>              // default
    println("-> Error: " + x)
    sender ! ("Unknown: " + x)
 }
}
```

Altogether

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Even compressed on a presentation slide, there isn't a lot of code!

```
import shapes._
import akka.actor._
import com.typesafe.config._

object Driver {
 def main(args:Array[String])={
  val sys = ActorSystem(…)
  val driver=sys.actorOf[Driver]
  val drawer=sys.actorOf[Drawer]
  driver ! Start(drawer)
 }
}
...
```

Application driver

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Here's the driver actor. It is declared as an "object" not a class, making it a singleton.
When we start, we send the "go!" message to the Driver actor that is defined on the next slide. This starts the asynchronous message passing.
The "!" is the message send method (stolen from Erlang).

```scala
import shapes._
import akka.actor._
import com.typesafe.config._

object Driver {
 def main(args:Array[String])={
  val sys = ActorSystem(…)
  val driver=sys.actorOf[Driver]
  val drawer=sys.actorOf[Drawer]
  driver ! Start(drawer)
 }
}
…
```

Singleton for main

Instantiate actors

Send a message to start the actors

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Here's the driver actor. It is declared as an "object" not a class, making it a singleton.
When we start, we send the "go!" message to the Driver actor that is defined on the next slide. This starts the asynchronous message passing.
The "!" is the message send method (stolen from Erlang).

Companion class

```
…
class Driver extends Actor {
  var drawer: Option[Drawer] =
    None

  def receive = {
    …
  }
}
```


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Here's the driver actor "companion class" for the object on the previous slide that held main.
Normally, you would not do such synchronous call and response coding, if avoidable, as it defeats the purpose of using actors for concurrency.

```
def receive = {
  case Start(d) =>
    drawer = Some(d)
    d ! Circle(Point(…),…)
    d ! Rectangle(…)
    d ! 3.14159
    d ! "exit"
  case "good bye!" =>
    println("<- cleaning up…")
    context.system.shutdown()
  case other =>
    println("<- " + other)
}
```

sent by driver

sent by drawer

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Here's the driver actor, a scala script (precompilation not required) to drive the drawing actor.
Normally, you would not do such synchronous call and response coding, if avoidable, as it defeats the purpose of using actors for concurrency.

```
d ! Circle(Point(…),…)
d ! Rectangle(…)
d ! 3.14159
d ! "exit"
```

```
-> drawing: Circle(Point(0.0,0.0),1.0)
-> drawing: Rectangle(Point(0.0,0.0),
2.0,5.0)
-> Error: 3.14159
-> exiting...
<- Shape drawn.
<- Shape drawn.
<- Unknown: 3.14159
<- cleaning up...
```

“<-” and “->” messages may be interleaved!!

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Note that the -> messages will always be in the same order and the <- will always be in the same order, but the two groups may be interleaved!!

```
…
// Drawing.receive
receive = {
 case s:Shape =>
  s.draw()
  self.reply("…")

 case …
 case …
}
```

Functional-style pattern matching

Object-oriented-style polymorphism

"Switch" statements are not (necessarily) evil

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The power of combining the best features of FP (pattern matching and "destructuring") and OOP (polymorphic behavior).

Exercise

Variations on an Actor theme.

drawing-actors.scala

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Refine Features

- Add more geometric shapes
- Add other messages for new behaviors.
  - Redraw all shapes drawn so far.
  - Clear the “screen”.
  - … (see the README).

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I believe another driver for FP's mainstream adoption will be the realization that it is ideal for data-centric applications, like “Big Data”.

Big Data

Data so big that traditional solutions are too slow, too small, or too expensive to use.

Hat tip: Bob Korbus

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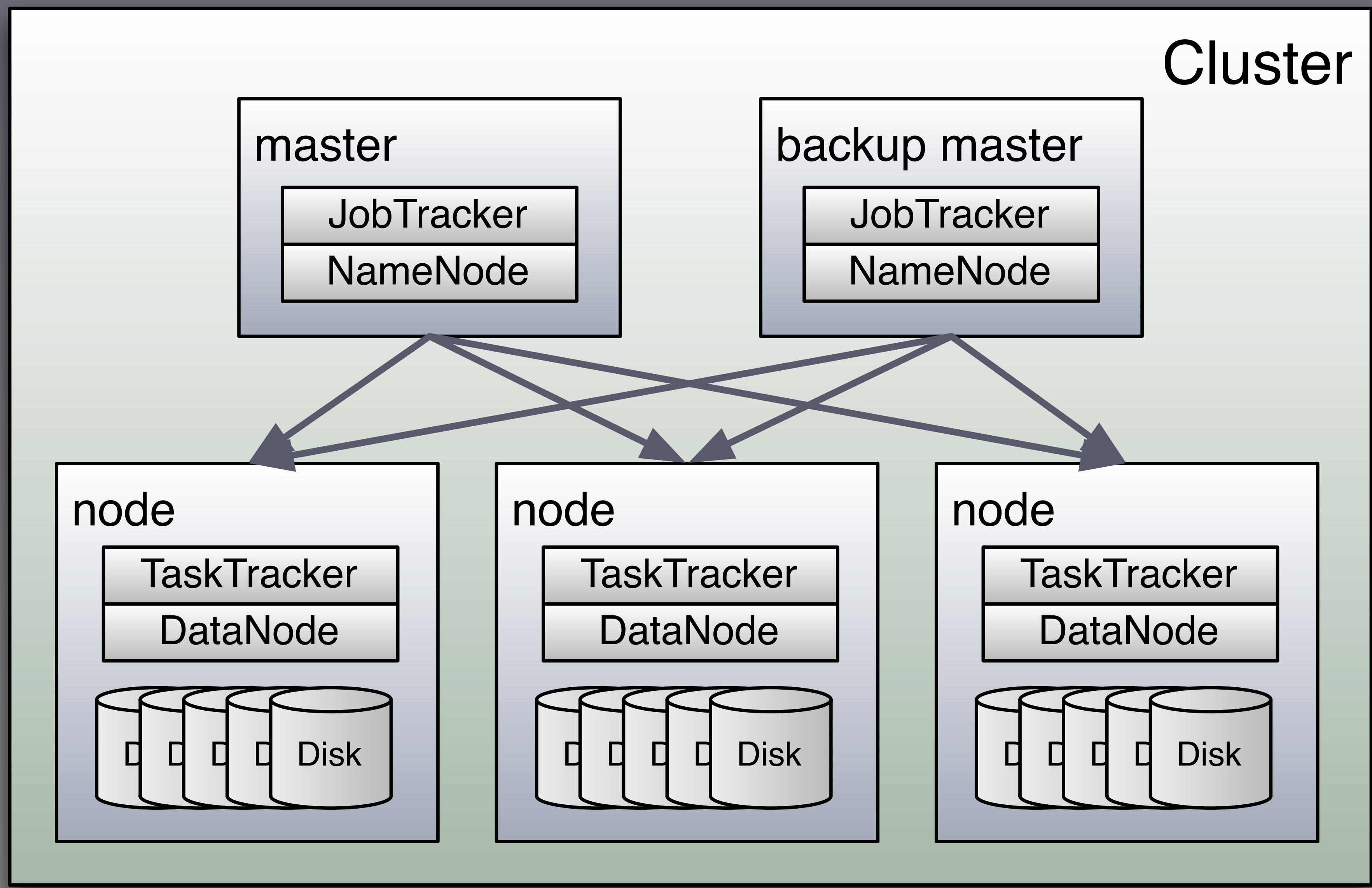
It's a buzz word, but generally associated with the problem of data sets too big to manage with traditional SQL databases. A parallel development has been the NoSQL movement that is good at handling semistructured data, scaling, etc.

Hadoop Crash Course

- The most popular, general-purpose, distributed data framework.

Hadoop Crash Course

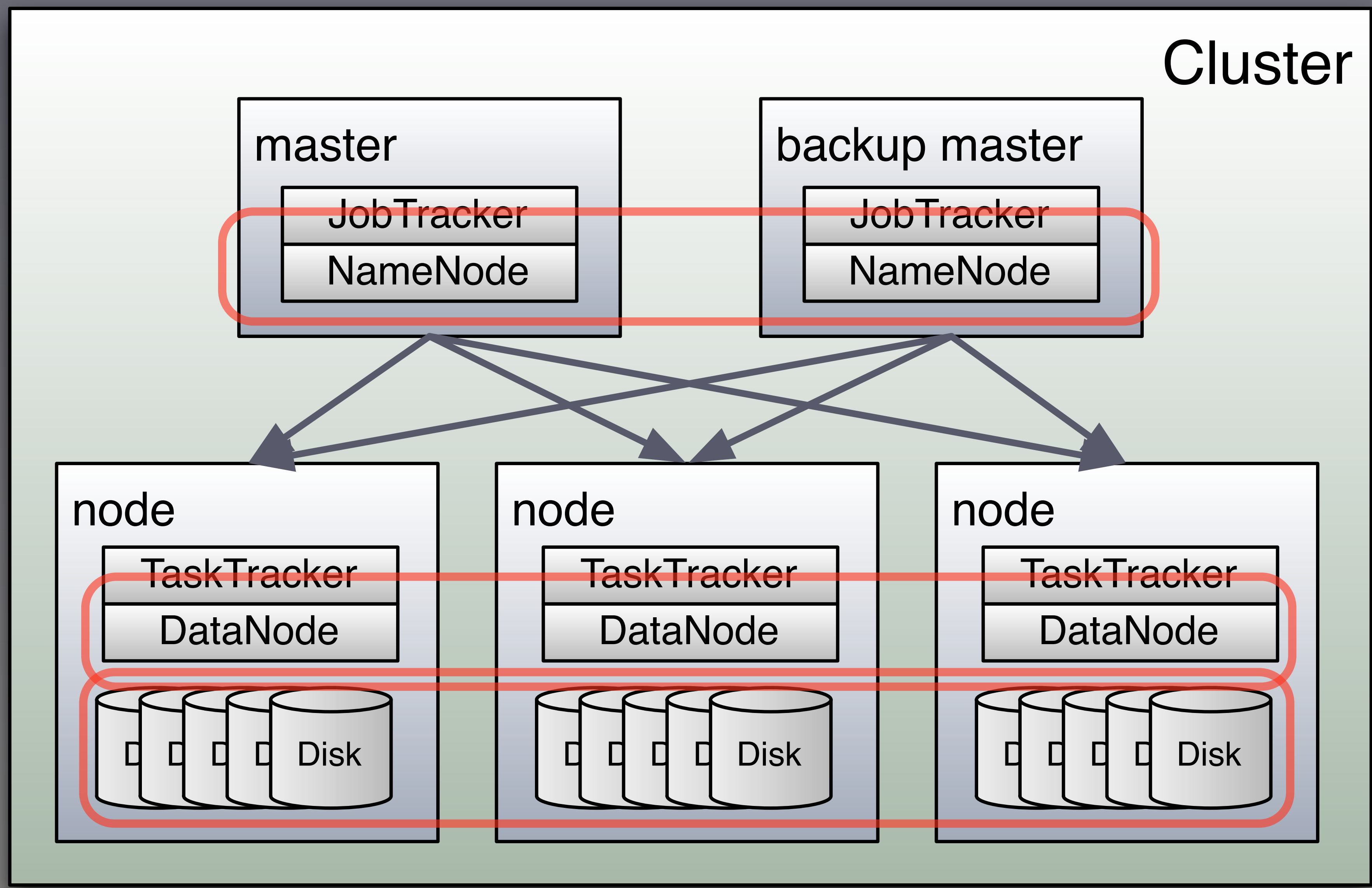


Hadoop Distributed File System (HDFS)

master daemon

slave daemons

storage



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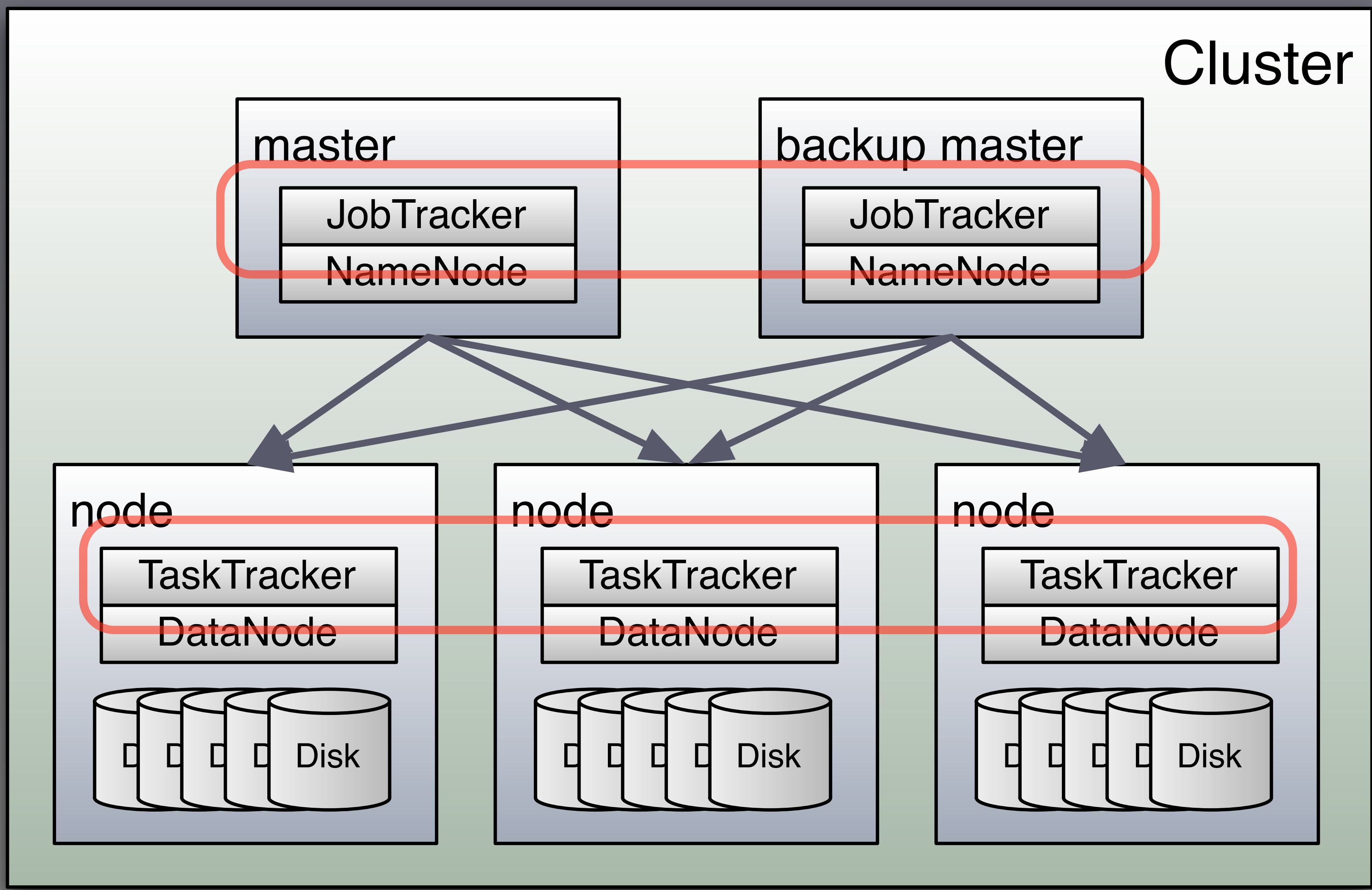
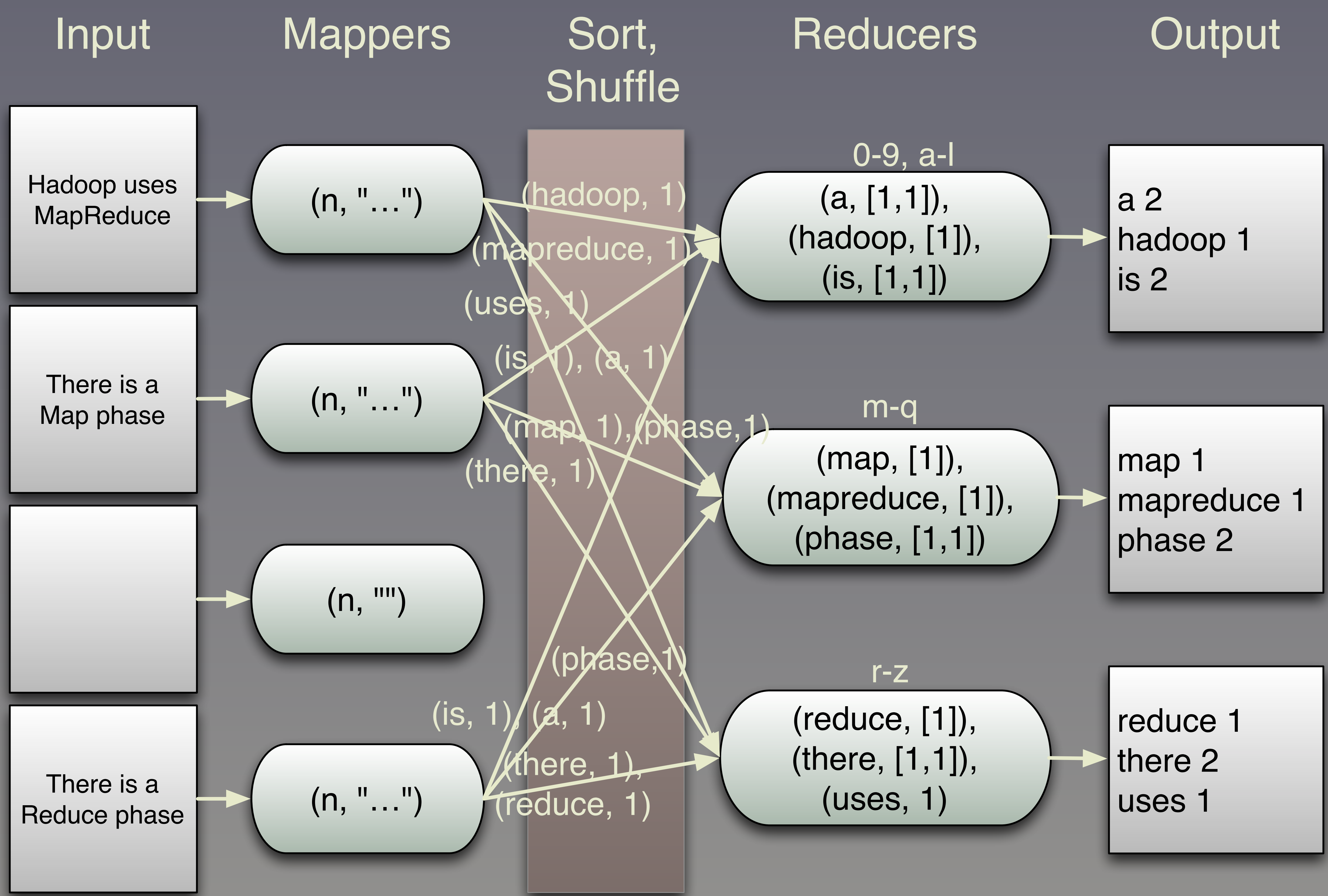
Hadoop Jobs

master daemon

slave daemons



What is MapReduce?



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The famous Word Count algorithm. We have a corpus of documents on the left. We want to parse and count the words. By default, each document gets a Map task (JVM process) - the rounded bubbled, which we have to implement. Each line of the file is passed in with it's position offset as the "key". We discard the key, tokenize the line, and emit new key-value pairs, each word and a count of 1, for every word found. (There are obvious optimizations to you could use…). Hadoop sorts the keys within each mapper task, then "shuffles" the key-value pairs over the cluster network to the appropriate reducer task (which we also must implement). We have set up the example so that all keys that start with 0 through 9 or a through l go to the 1st reducer, etc. Finally, each reducer is passed the keys, one at a time, with a collection of the counts for each key. The reducer sums the collections and writes the output, at least one file per reducer.

Hadoop Languages and Tools

- Hive: SQL queries.
- Pig: Dataflow language.
- Java API: “Assembly language”.
- Cascading: High-level Java API.
- Scalding: Scala Cascading API.

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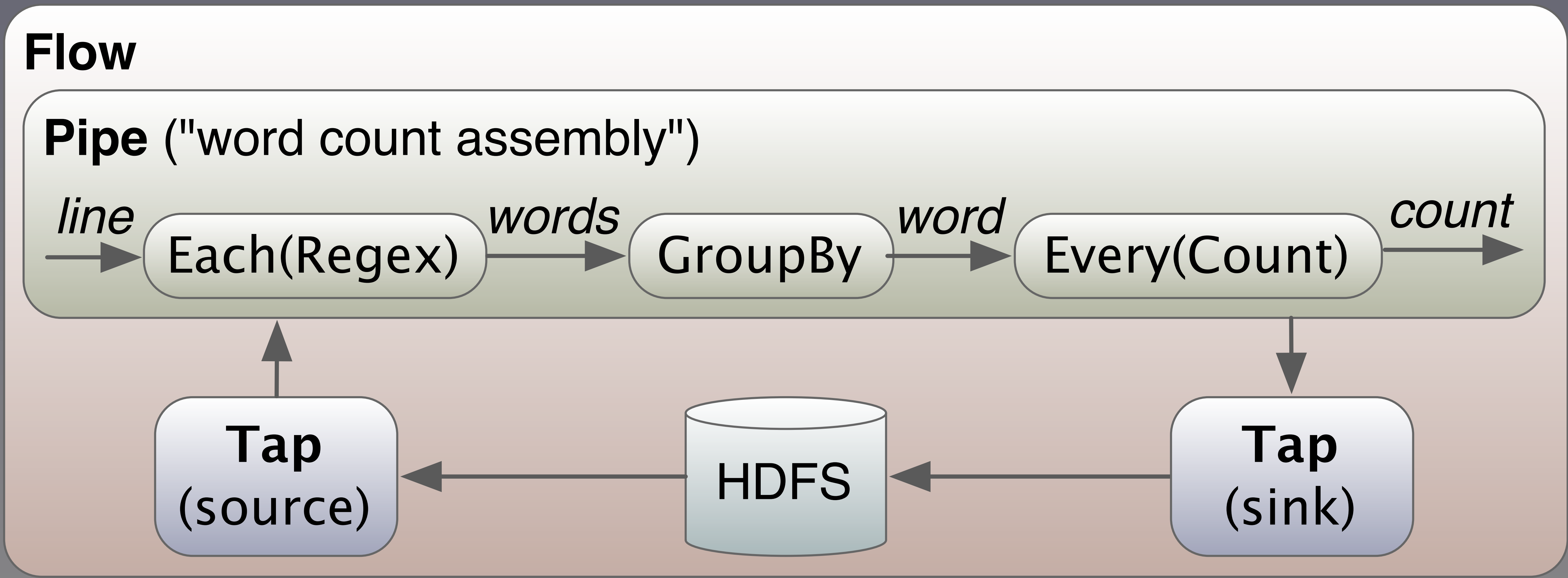
And there are other options… The 1st three are “standard” parts of Hadoop distros, with the Java API being the lowest-level API (and tedious to use). Think of Win32 or X-Windows APIs (if you’re old enough ;)

Cascading is a popular, 3rd-party Java API with higher abstractions for dataflows and standard relational operations, like joins, group-bys, etc. Scalding provides a Scala API on cascading that really exposed the abstractions beautifully, as we’ll see.

Cascading

Data flows consist of source and sink Taps connected by Pipes.

Cascading



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```java
import org.cascading.*;
...
public class WordCount {
  public static void main(String[] args) {
    String inputPath  = args[0];
    String outputPath = args[1];
    Properties properties = new Properties();
    FlowConnector.setApplicationJarClass( properties, Main.class );

    Scheme sourceScheme = new TextLine( new Fields( "line" ) );
    Scheme sinkScheme = new TextLine( new Fields( "word", "count" ) );
    Tap source = new Hfs( sourceScheme, inputPath );
    Tap sink   = new Hfs( sinkScheme, outputPath, SinkMode.REPLACE );

    Pipe assembly = new Pipe( "wordcount" );

    String regex = "(?<!\\pL)(?=\\pL)[^ ]*(?<=\\pL)(?!\\pL)";
    Function function = new RegexGenerator( new Fields( "word" ), regex );
    assembly = new Each( assembly, new Fields( "line" ), function );
    assembly = new GroupBy( assembly, new Fields( "word" ) );
    Aggregator count = new Count( new Fields( "count" ) );
    assembly = new Every( assembly, count );

    FlowConnector flowConnector = new FlowConnector( properties );
    Flow flow = flowConnector.connect( "word-count", source, sink, assembly);
    flow.complete();
  }
}
```


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Here is the Cascading Java code. It's cleaner than the MapReduce API, because the code is more focused on the algorithm with less boilerplate, although it looks like it's not that much shorter. HOWEVER, this is all the code, where as previously I omitted the setup (main) code. See http://docs.cascading.org/cascading/1.2/userguide/html/ch02.html for details of the API features used here; we won't discuss them here, but just mention some highlights.

Note all the green types, but many represent "functions" to apply to the data, such as Count, Each, GroupBy, etc. I won't show the corresponding low-level Java API code, but Cascading does a good job emphasizing composition of behaviors and minimizing framework boilerplate.

Scalding

Scala API on top of Cascading.

Developed at Twitter.

github.com/twitter/scalding

```scala
import com.twitter.scalding._

class WordCountJob(args: Args) extends
Job(args) {
  TextLine( args("input") )
    .read
    .flatMap('line -> 'word) {
      line: String =>
        line.trim.toLowerCase
            .split("\\W+")
    }
    .groupBy('word) {
      group => group.size('count) }
  }
  .write(Tsv(args("output")))
}
```

That's it!

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Note that the green types have been replaced by yellow functions that we string together to process the data pipeline. Almost all boiler plate has disappeared.

```scala
import com.twitter.scalding._

class WordCountJob(args: Args) extends
Job(args) {
  TextLine( args("input") )
    .read
    .flatMap('line -> 'word) {
      line: String =>
        line.trim.toLowerCase
            .split("\\W+")
    }
    .groupBy('word) {
      group => group.size('count) }
  }
  .write(Tsv(args("output")))
}
```

Imports

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Import the top-level library abstractions.

```scala
import com.twitter.scalding._

class WordCountJob(args: Args) extends
Job(args) {
  TextLine( args("input") )
    .read
    .flatMap('line -> 'word) {
      line: String =>
        line.trim.toLowerCase
            .split("\\W+")
    }
    .groupBy('word) {
      group => group.size('count) }
  }
  .write(Tsv(args("output")))
}
```

A *Job*
class

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Wrap the logic in a class (OOP!) that extends the Job abstraction.

```
import com.twitter.scalding._

class WordCountJob(args: Args) extends
Job(args) {
  TextLine( args("input") )
    .read
    .flatMap('line -> 'word) {
      line: String =>
        line.trim.toLowerCase
            .split("\\W+")
    }
    .groupBy('word) {
      group => group.size('count) }
  }
  .write(Tsv(args("output")))
}
```

Open the text file input

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The "args" holds the user-specified arguments used to invoke the job. "--input path" specifies the source of the text. Similarly, "--output path" is used to specify the output location for the results.

```
import com.twitter.scalding._

class WordCountJob(args: Args) extends
Job(args) {
  TextLine( args("input") )
    .read
    .flatMap('line -> 'word) {
      line: String =>
        line.trim.toLowerCase
            .split("\\W+")
    }
    .groupBy('word) {
      group => group.size('count) }
  }
  .write(Tsv(args("output")))
}
```

Split each line into words

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A flatMap iterates through a collection, calling a function on each element, where the function "converts" each element into a collection. So, you get a collection of collections. The "flat" part flattens those nested collections into one larger collection. The "line: String => line …("\\W+")" expression is the function called by flatMap on each element, where the argument to the function is a single string variable named line and the body is to the right-hand side of the =>.
The output word field is called "word", from the first argument to flatMap: "'line -> 'word".

```scala
import com.twitter.scalding._

class WordCountJob(args: Args) extends
Job(args) {
  TextLine( args("input") )
    .read
    .flatMap('line -> 'word) {
      line: String =>
        line.trim.toLowerCase
            .split("\\W+")
    }
    .groupBy('word) {
      group => group.size('count) }
  }
  .write(Tsv(args("output")))
}
```

Group by each word and count the group sizes

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A flatMap iterates through a collection, calling a function on each element, where the function "converts" each element into a collection. So, you get a collection of collections. The "flat" part flattens those nested collections into one larger collection. The "line: String => line …("\\W+")" expression is the function called by flatMap on each element, where the argument to the function is a single string variable named line and the body is to the right-hand side of the =>.
The output word field is called "word", from the first argument to flatMap: "'line -> 'word".

```scala
import com.twitter.scalding._

class WordCountJob(args: Args) extends
Job(args) {
  TextLine( args("input") )
    .read
    .flatMap('line -> 'word) {
      line: String =>
        line.trim.toLowerCase
            .split("\\W+")
    }
    .groupBy('word) {
      group => group.size('count) }
  }
  .write(Tsv(args("output")))
}
```

Write tab-separated words and counts

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Finally, we write the tab-separated words and counts to the output location specified using “--output path”.

```scala
import com.twitter.scalding._

class WordCountJob(args: Args) extends
Job(args) {
  TextLine( args("input") )
    .read
    .flatMap('line -> 'word) {
      line: String =>
        line.trim.toLowerCase
            .split("\\W+")
    }
    .groupBy('word) {
      group => group.size('count) }
  }
  .write(Tsv(args("output")))
}
```

Profit!!

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Scalding adds a built-in Matrix library (linear algebra) and a separate Algebra project called Algebird.

github.com/twitter/algebird

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These are extensions beyond what Cascading provides.

Exercise

Scalding “Workshop”:
WordCount2.scala,
StockAverages3.scala

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I’ve provided a snapshot of a Scalding tutorial I’ve written from https://github.com/deanwampler/scalding-workshop. We’ll do a few of the examples from there now.

Joins

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Doing relational-style joins.

```
import com.twitter.scalding._

class StocksDivsJoin(args: Args) extends Job(args){
  val stocksSchema = ('symd, 'close, 'volume)
  val divsSchema = ('dymd, 'dividend)
  val stocksPipe = new Tsv(args("stocks"), stockSchema)
    .read
    .project('symd, 'close)
  val divsPipe = new Tsv(args("dividends"), divsSchema)
    .read

  stocksPipe
    .joinWithTiny('symd -> 'dymd, dividendsPipe)
    .project('symd, 'close, 'dividend)
    .write(Tsv(args("output")))
```

Inner join of stocks and dividends

```scala
import com.twitter.scalding._

class StocksDivsJoin(args: Args) extends Job(args){
  val stocksSchema = ('symd, 'close, 'volume)
  val divsSchema = ('dymd, 'dividend)
  val stocksPipe = new Tsv(args("stocks"), stockSchema)
    .read
    .project('symd, 'close)
  val divsPipe = new Tsv(args("dividends"), divsSchema)
    .read

  stocksPipe
    .joinWithTiny('symd -> 'dymd, dividendsPipe)
    .project('symd, 'close, 'dividend)
    .write(Tsv(args("output")))
```

Define the schemas as values.

```scala
import com.twitter.scalding._

class StocksDivsJoin(args: Args) extends Job(args){
  val stocksSchema = ('symd, 'close, 'volume)
  val divsSchema = ('dymd, 'dividend)
  val stocksPipe = new Tsv(args("stocks"), stockSchema)
    .read
    .project('symd, 'close)
  val divsPipe = new Tsv(args("dividends"), divsSchema)
    .read

  stocksPipe
    .joinWithTiny('symd -> 'dymd, dividendsPipe)
    .project('symd, 'close, 'dividend)
    .write(Tsv(args("output")))
```

Separate pipes for the two sources.
Project out the fields we want.

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```scala
import com.twitter.scalding._

class StocksDivsJoin(args: Args) extends Job(args){
  val stocksSchema = ('symd, 'close, 'volume)
  val divsSchema = ('dymd, 'dividend)
  val stocksPipe = new Tsv(args("stocks"), stockSchema)
    .read
    .project('symd, 'close)
  val divsPipe = new Tsv(args("dividends"), divsSchema)
    .read

  stocksPipe
    .joinWithTiny('symd -> 'dymd, dividendsPipe)
    .project('symd, 'close, 'dividend)
    .write(Tsv(args("output")))
```

Join stocks with smaller dividends on the year-month-day. Project the output fields.

Exercise

Scalding "Workshop":

StocksDividendsJoin4.scala

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I've provided a snapshot of a Scalding tutorial I've written from https://github.com/deanwampler/scalding-workshop. We'll do a few of the examples from there now.

```
# Invoking the script (bash)
run.rb StocksDivsJoins.scala \
  --stocks    data/stocks/IBM.txt \
  --dividends data/dividends/IBM.txt \
  --output output/IBM-join.txt

# Output (not sorted!)
2010-02-08      121.88  0.55
2009-11-06      123.49  0.55
2009-08-06      117.38  0.55
2009-05-06      104.62  0.55
2009-02-06      96.14   0.5
2008-11-06      85.15   0.5
2008-08-06      129.16  0.5
2008-05-07      124.14  0.5
...
```

N-Grams

Doing relational-style joins.

```scala
import com.twitter.scalding._

class ContextNGrams(args: Args) extends Job(args) {
  val ngramPrefix =
    args.list("ngram-prefix").mkString(" ")
  val keepN = args.getOrElse("count", "10").toInt
  val ngramRE = (ngramPrefix + """\s+(\w+)""").r

  // Sort (phrase,count) by count, descending.
  val countReverseComparator =
    (tuple1:(String,Int), tuple2:(String,Int))
      => tuple1._2 > tuple2._2
  ...
```

1st half...

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```
  ...
  val lines = TextLine(args("input"))
    .read
    .flatMap('line -> 'ngram) { text: String =>
      ngramRE.findAllIn(text).toIterable }
    .discard('num, 'line)
    .groupBy('ngram) { g => g.size('count) }
    .groupAll { g =>
      g.sortWithTake[(String,Int)](
       ('ngram, 'count) -> 'sorted_ngrams, keepN)(
       countReverseComparator)
    }
    .write(Tsv(args("output")))
}
```

... 2nd half.

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```scala
import com.twitter.scalding._

class ContextNGrams(args: Args) extends Job(args) {
  val ngramPrefix =
    args.list("ngram-prefix").mkString(" ")
  val keepN = args.getOrElse("count", "10").toInt
  val ngramRE = (ngramPrefix + """\s+(\w+)""").r

  // Sort (phrase,count) by count, descending.
  val countReverseComparator =
    (tuple1:(String,Int), tuple2:(String,Int))
      => tuple1._2 > tuple2._2
  ...
```

The n-gram prefix (e.g., "I love") and how many to find (ordered by frequency).

```scala
import com.twitter.scalding._

class ContextNGrams(args: Args) extends Job(args) {
  val ngramPrefix =
    args.list("ngram-prefix").mkString(" ")
  val keepN = args.getOrElse("count", "10").toInt
  val ngramRE = (ngramPrefix + """\s+(\w+)""").r

  // Sort (phrase,count) by count, descending.
  val countReverseComparator =
    (tuple1:(String,Int), tuple2:(String,Int))
      => tuple1._2 > tuple2._2
  ...
```

A regex for finding the ngrams.

```scala
import com.twitter.scalding._

class ContextNGrams(args: Args) extends Job(args) {
  val ngramPrefix =
    args.list("ngram-prefix").mkString(" ")
  val keepN = args.getOrElse("count", "10").toInt
  val ngramRE = (ngramPrefix + """\s+(\w+)""").r

  // Sort (phrase,count) by count, descending.
  val countReverseComparator =
    (tuple1:(String,Int), tuple2:(String,Int))
      => tuple1._2 > tuple2._2
  ...
```

Function we'll use to sort n-grams by frequency, descending.

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```
  ...
  val lines = TextLine(args("input"))
    .read
    .flatMap('line -> 'ngram) { text: String =>
      ngramRE.findAllIn(text).toIterable }
    .discard('num, 'line)
    .groupBy('ngram) { g => g.size('count) }
    .groupAll { g =>
      g.sortWithTake[(String,Int)](
       ('ngram, 'count) -> 'sorted_ngrams, keepN)(
       countReverseComparator)
    }
    .write(Tsv(args("output")))
}
```

Read lines, find n-grams, discard some fields, group by n-gram.

```
  ...
  val lines = TextLine(args("input"))
    .read
    .flatMap('line -> 'ngram) { text: String =>
      ngramRE.findAllIn(text).toIterable }
    .discard('num, 'line)
    .groupBy('ngram) { g => g.size('count) }
    .groupAll { g =>
      g.sortWithTake[(String,Int)](
       ('ngram, 'count) -> 'sorted_ngrams, keepN)(
       countReverseComparator)
    }
    .write(Tsv(args("output")))
}
```

"Group all" (n-gram, count) together, sort by count, write out.

Exercise

Scalding "Workshop":

ContextNGrams7.scala

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I've provided a snapshot of a Scalding tutorial I've written from https://github.com/deanwampler/scalding-workshop. We'll do a few of the examples from there now.

```
# Invoking the script (bash)
run ContextNGrams.scala \
  --input  data/shakespeare/plays.txt \
  --output output/context-ngrams.txt \
  --ngram-prefix "I love" \
  --count 10

# Output (reformatted)
(I love thee,44),
(I love you,24),
(I love him,15),
(I love the,9),
(I love her,8),
...,
(I love myself,3),
...,
(I love Valentine,1),
...,
(I love France,1), ...
```

Matrices

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Doing relational-style joins.

```scala
import com.twitter.scalding._
import com.twitter.scalding.mathematics.Matrix
// Load a directed graph adjacency matrix where:
// a[i,j] = 1 if there is an edge from a[i] to b[j]
// and computes the cosine of the angle between
// every two pairs of vectors.
class MatrixCosine(args: Args) extends Job(args) {
  import Matrix._
  val schema = ('user1, 'user2, 'relation)
  val adjacencyMatrix = Tsv(args("input"), schema)
    .read
    .toMatrix[Long,Long,Double](schema)
  val normMatrix = adjacencyMatrix.rowL2Normalize

  // Inner product is equivalent to the cosine:
  //   AA^T/(||A||*||A||)
  (normMatrix * normMatrix.transpose)
  .write(Tsv(args("output")))
}
```

```scala
import com.twitter.scalding._
import com.twitter.scalding.mathematics.Matrix
// Load a directed graph adjacency matrix where:
// a[i,j] = 1 if there is an edge from a[i] to b[j]
// and computes the cosine of the angle between
// every two pairs of vectors.
class MatrixCosine(args: Args) extends Job(args) {
  import Matrix._
  val schema = ('user1, 'user2, 'relation)
  val adjacencyMatrix = Tsv(args("input"), schema)
    .read
    .toMatrix[Long,Long,Double](schema)
  val normMatrix = adjacencyMatrix.rowL2Normalize

  // Inner product is equivalent to the cosine:
  //   AA^T/(||A||*||A||)
  (normMatrix * normMatrix.transpose)
  .write(Tsv(args("output")))
}
```

imports

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```scala
import com.twitter.scalding._
import com.twitter.scalding.mathematics.Matrix
// Load a directed graph adjacency matrix where:
// a[i,j] = 1 if there is an edge from a[i] to b[j]
// and computes the cosine of the angle between
// every two pairs of vectors.
class MatrixCosine(args: Args) extends Job(args) {
  import Matrix._
  val schema = ('user1, 'user2, 'relation)
  val adjacencyMatrix = Tsv(args("input"), schema)
    .read
    .toMatrix[Long,Long,Double](schema)
  val normMatrix = adjacencyMatrix.rowL2Normalize

  // Inner product is equivalent to the cosine:
  //   AA^T/(||A||*||A||)
  (normMatrix * normMatrix.transpose)
  .write(Tsv(args("output")))
}
```

Cosine!

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sqrt(x^2+y^2) normalization, i.e., the Euclidean distance.

Final Exercise

- Pick either of the following Akka or Scalding tutorial on GitHub and work start it.
  - github.com/henrikengstrom/akka-meetup-sthlm
  - github.com/deanwampler/scalding-workshop

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I've provided a snapshot of a Scalding tutorial I've written from https://github.com/deanwampler/scalding-workshop. We'll do a few of the examples from there now.


Recap

Akka is a powerful toolkit for distributed applications.

Scalding is a great example of why FP is ideal for data problems.

Thanks!

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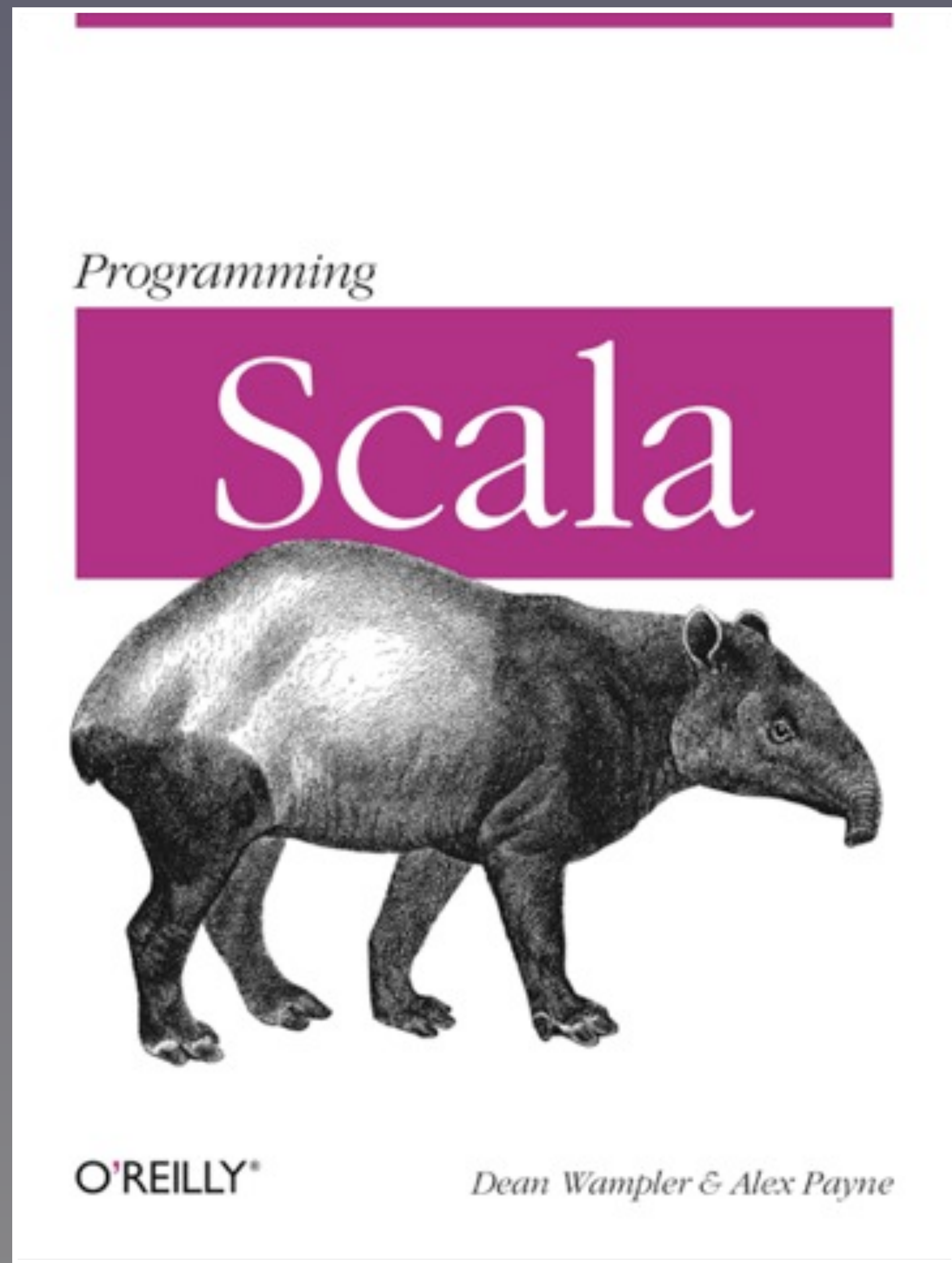

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