High-level concurrency concepts

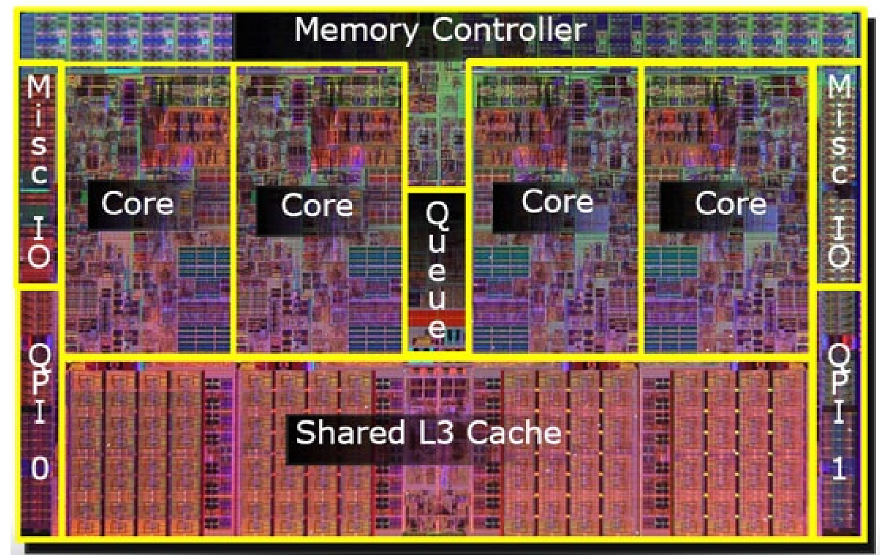
Václav Pech

NPRG014 2021/2022

http://www.vaclavpech.eu

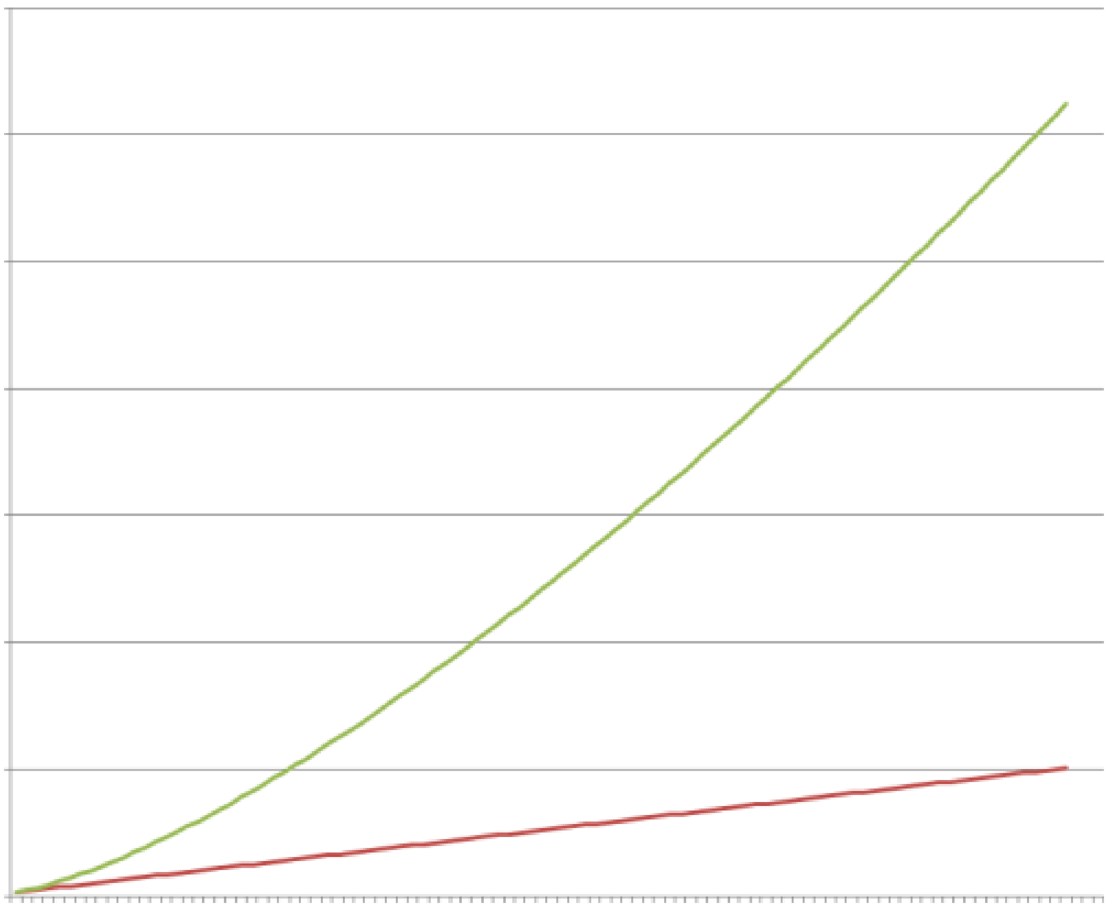
@vaclav_pech

Why concurrency?



We're all in the parallel computing business!

of cores



JVM machinery

Thread, Runnable, Thread Pools

JVM machinery

Thread, Runnable, Thread Pools

Synchronized blocks

Volatile

Locks

Atomic

Dealing with threads sucks!

```
public class Counter {
    private static long count = 0;

    public Counter() {

        count++;

    }
}
```

Dealing with threads sucks!

```
public class Counter {
    private volatile static long count = 0;

    public Counter() {

        count++;

    }
}
```

Dealing with threads sucks!

```java
public class Counter {
    private volatile static long count = 0;

    public Counter() {

        count = count + 1;

    }
}
```

Dealing with threads sucks!

```java
public class Counter {
    private static long count = 0;

    public Counter() {
        synchronized (this) {
            count++;
        }
    }
}
```

Dealing with threads sucks!

```java
public class Counter {
    private static long count = 0;

    public Counter() {
        synchronized (this.getClass()) {
            count++;
        }
    }
}
```

Dealing with threads sucks!

```
public class Counter {
    private static Long count = 0;

    public Counter() {
        synchronized (count) {
            count++;
        }
    }
}
```

Dealing with threads sucks!

```java
public class Counter {
    private static Long count = 0;

    public Counter() {
        synchronized (count) {
            count = new Long(count.longValue() + 1);
        }
    }
}
```

Dealing with threads sucks!

```java
public class ClickCounter implements ActionListener {
    public ClickCounter(JButton button) {
        button.addActionListener(this);
    }

    public void actionPerformed(final ActionEvent e) {
        ...
    }
}
```

Stone age of parallel SW

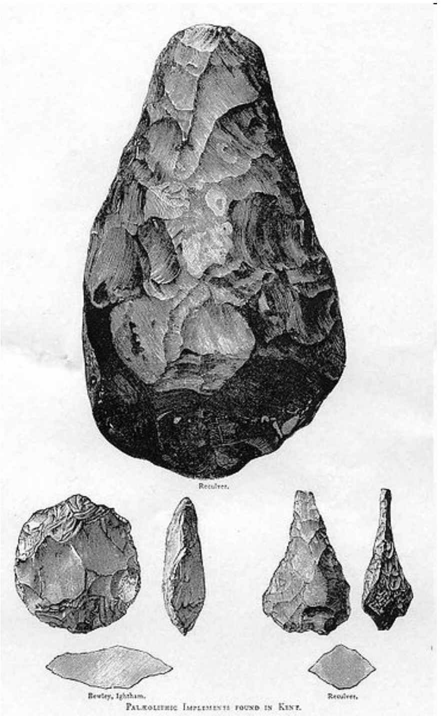
Dead-locks

Live-locks

Race conditions

Starvation

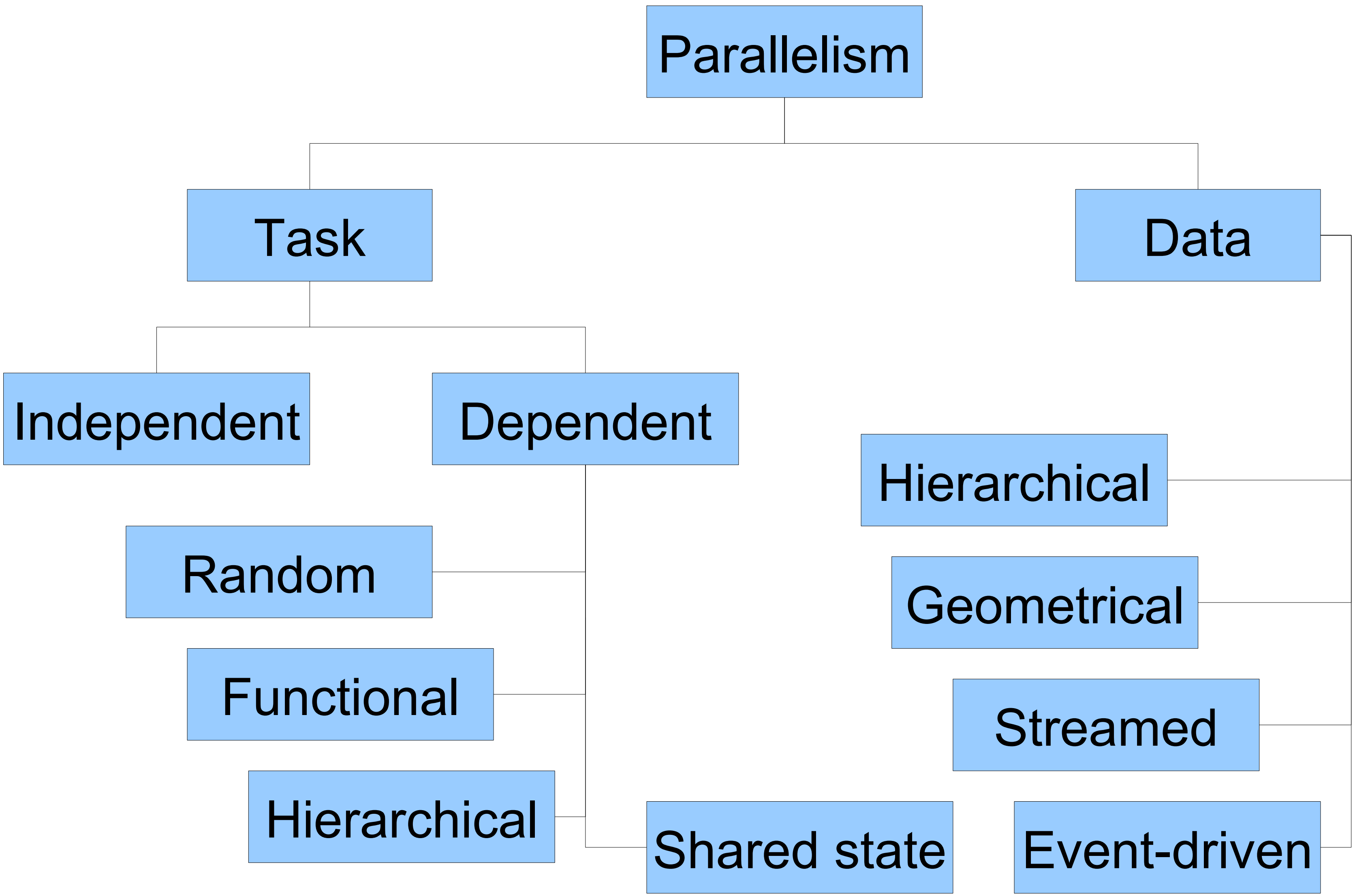
Shared Mutable State



Why high-level concurrency?

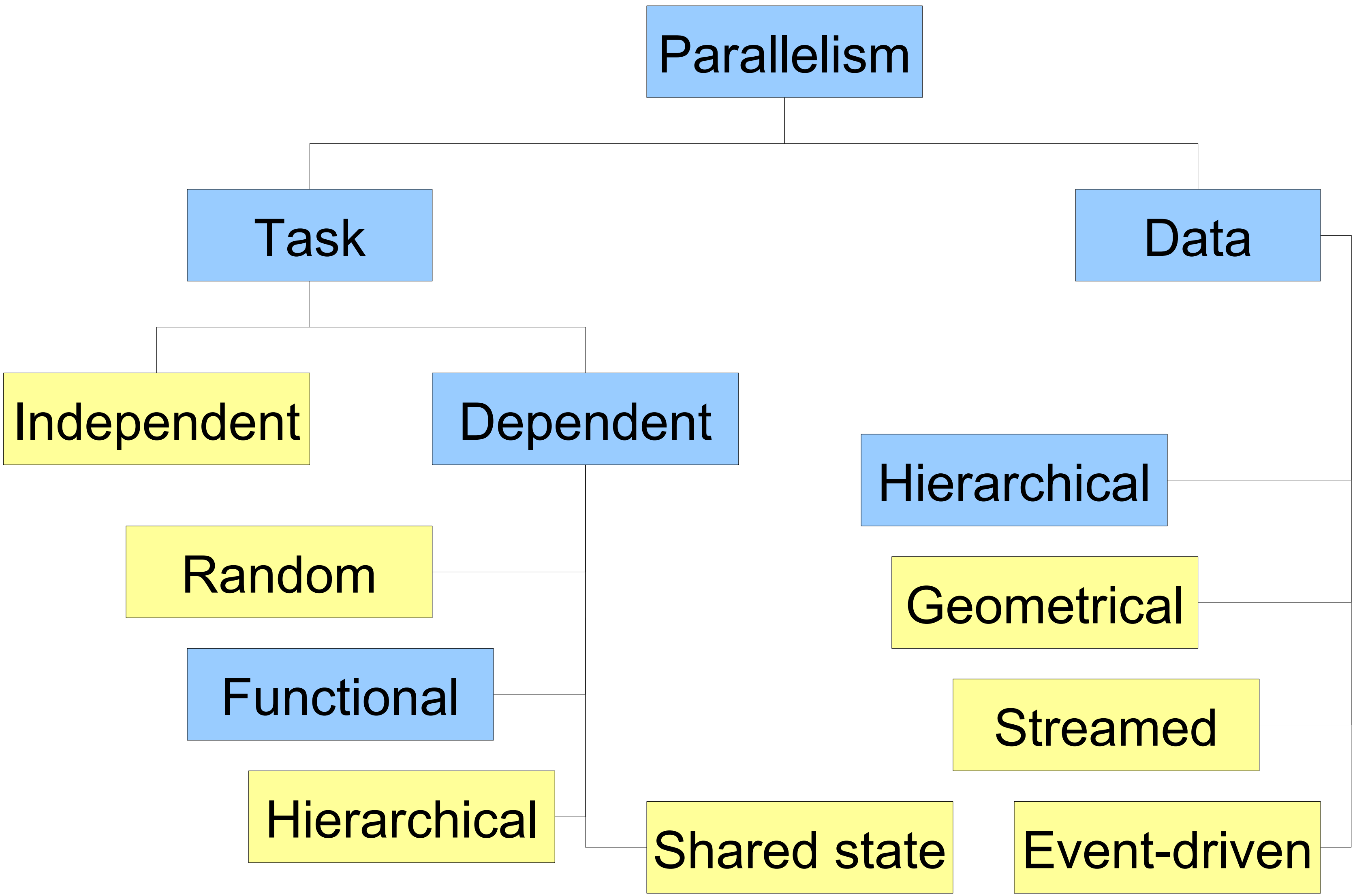
Multithreaded programs today work mostly by accident!

Structure



Parallelism
Task
Data
Independent
Dependent
Random
Functional
Hierarchical
Shared state
Hierarchical
Geometrical
Streamed
Event-driven

Structure


Parallelism
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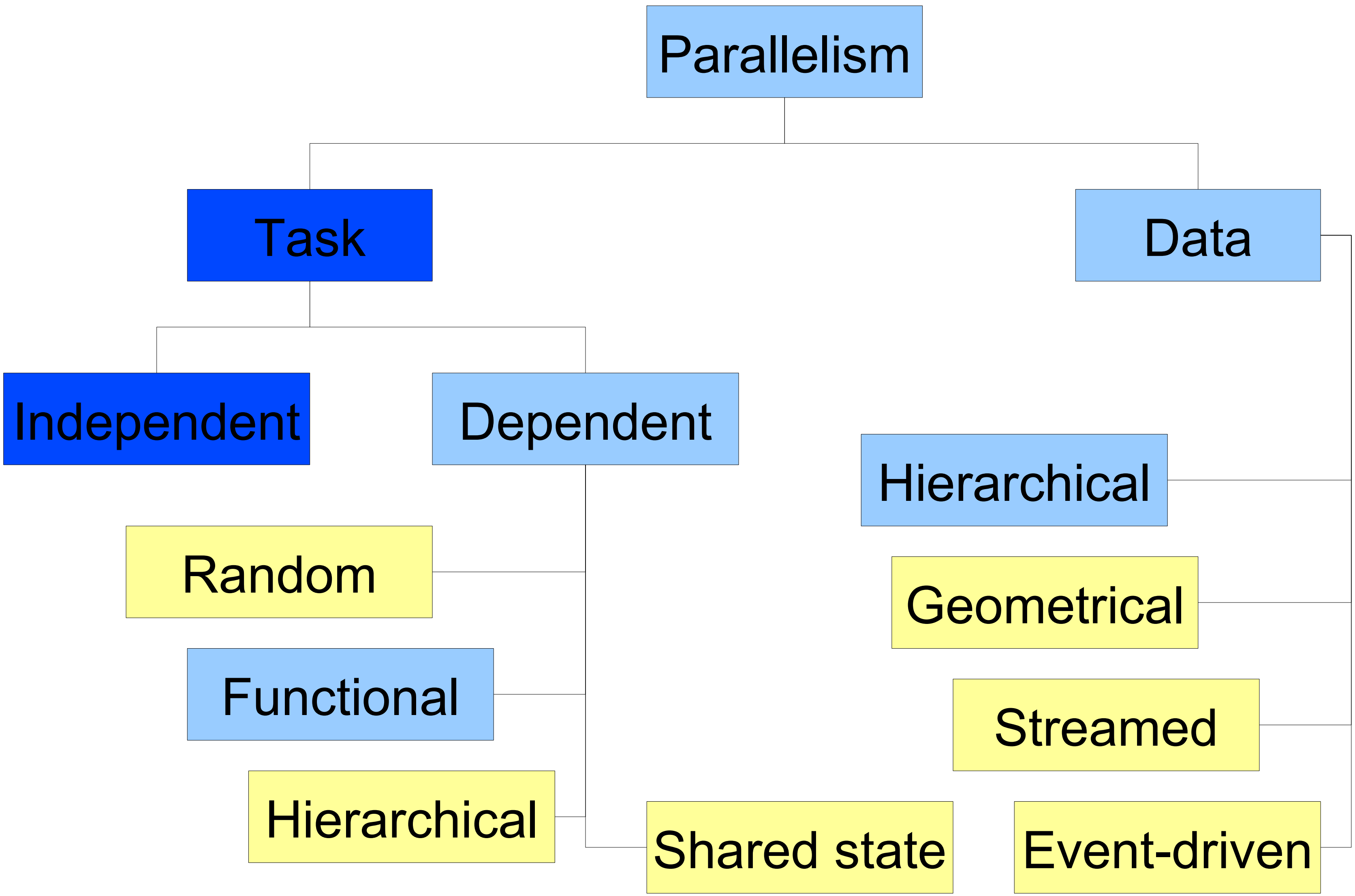
Shared state
Event-driven

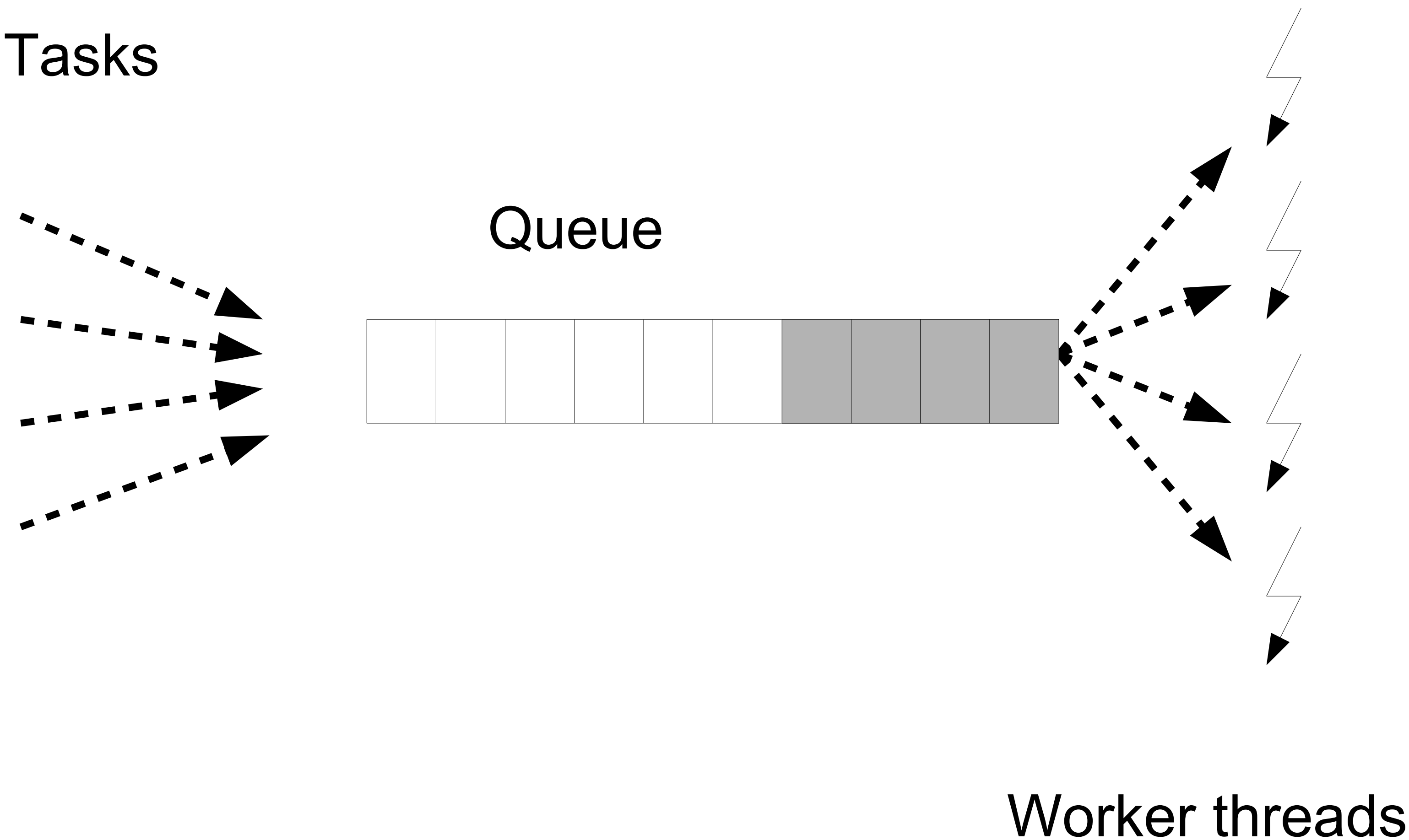
Task parallelism



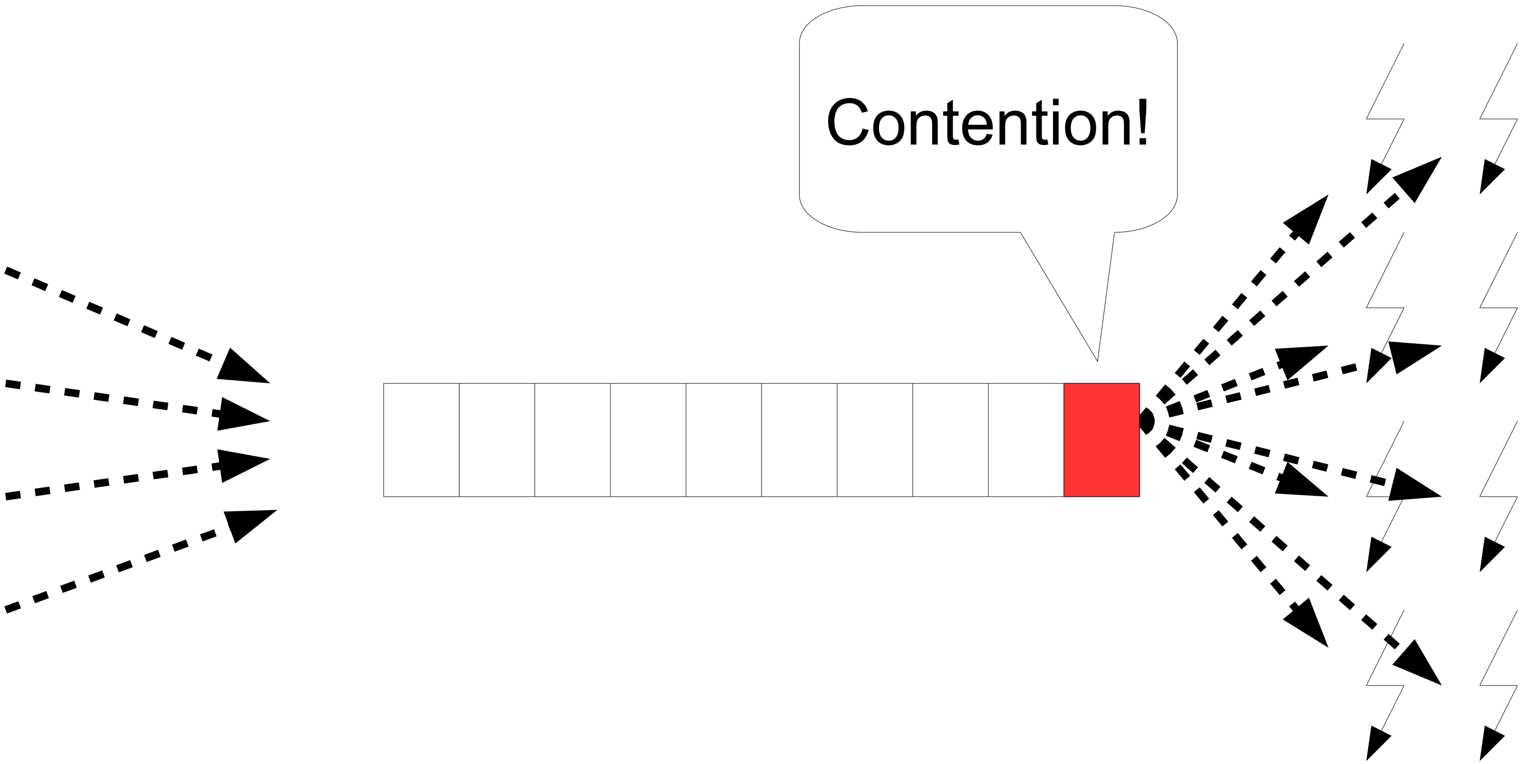
Asynchronous invocation

```
Future f = threadPool.submit(calculation);
…
System.out.println(“Result: “ + f.get());
```

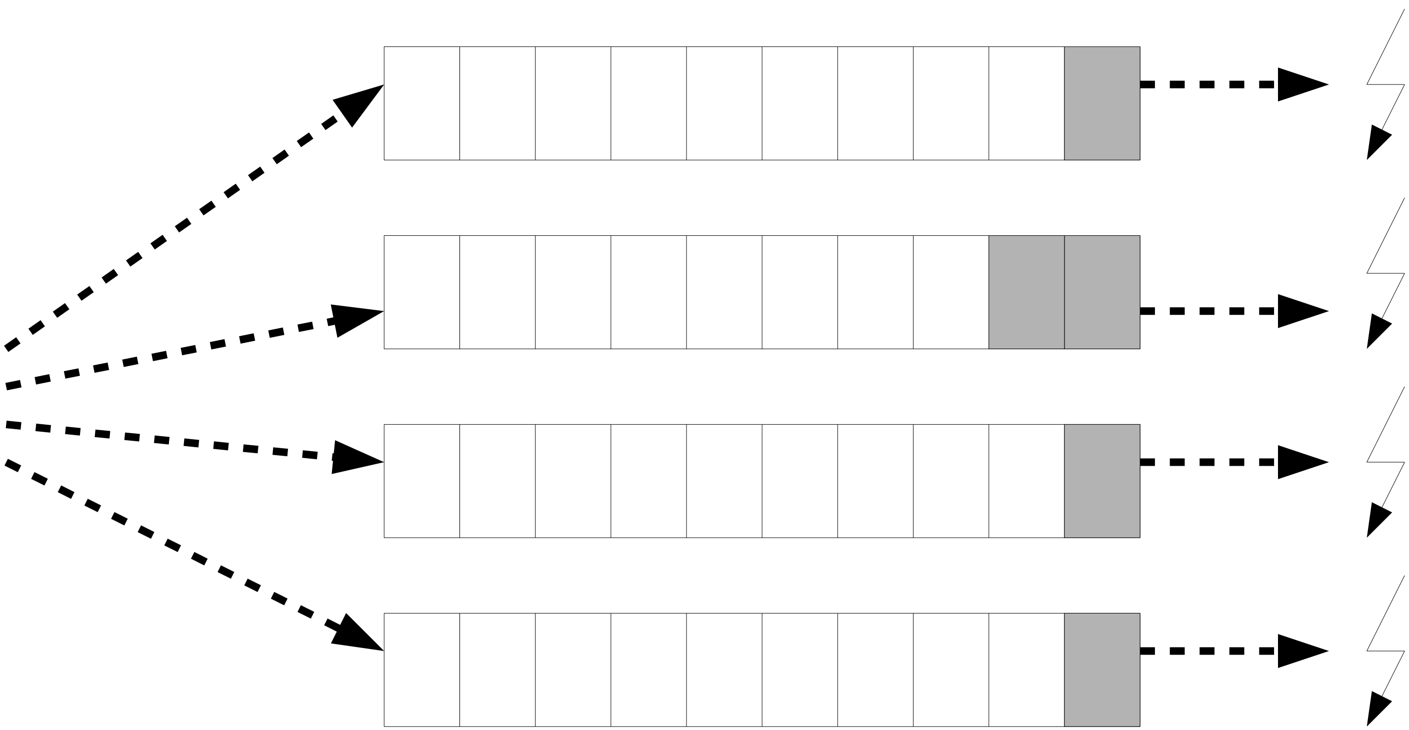
Thread Pool



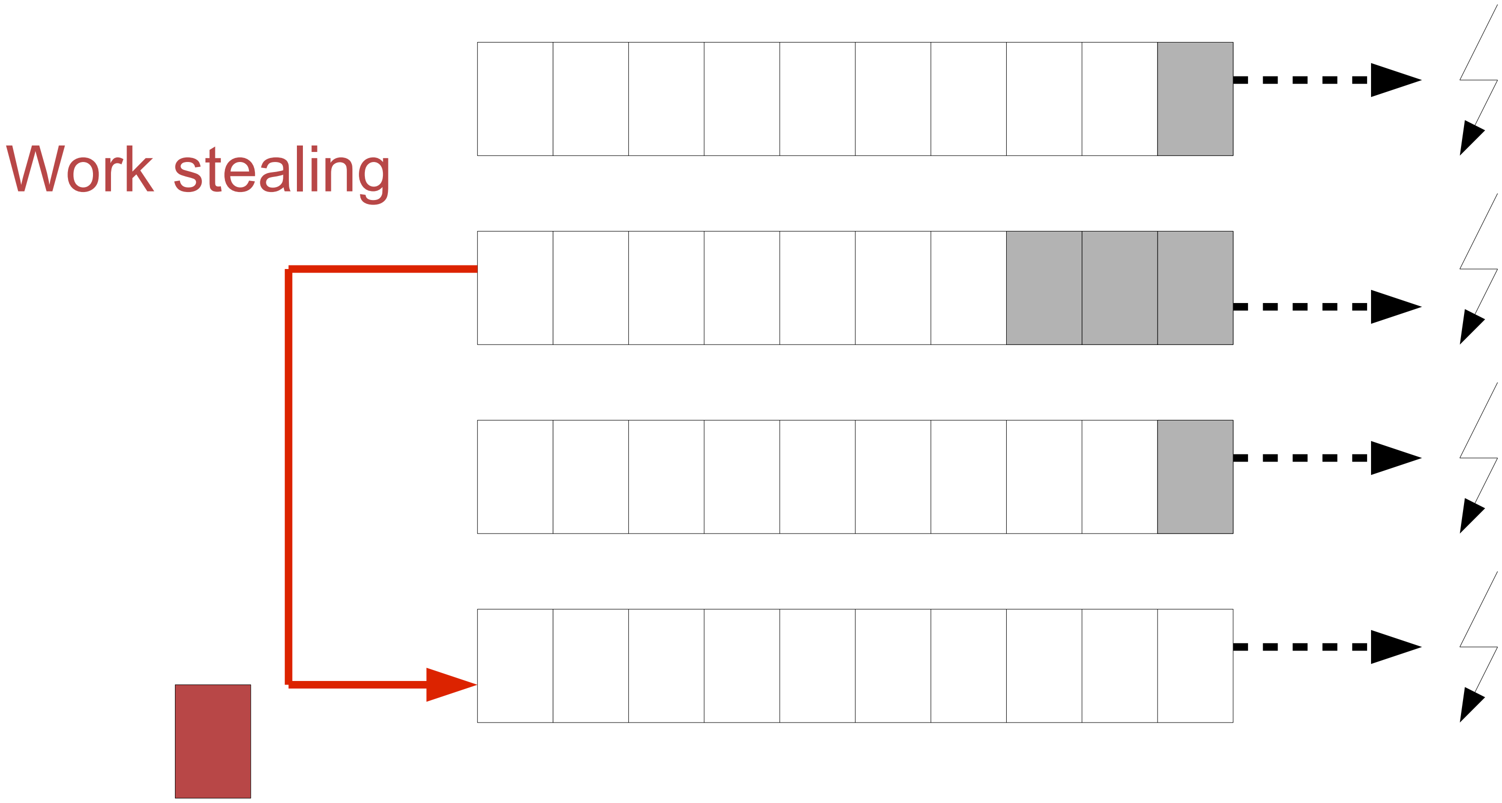
Thread Pool



Fork/Join Thread Pool



Fork/Join Thread Pool



Async the Groovy way

```
task {
    calculation.process()
}
```

Async the Groovy way

```
def group = new NonDaemonPGroup(10)

group.task {
    calculation.process()
}
```

Async the Groovy way

group.task {->…}

group.task new Runnable() {…}

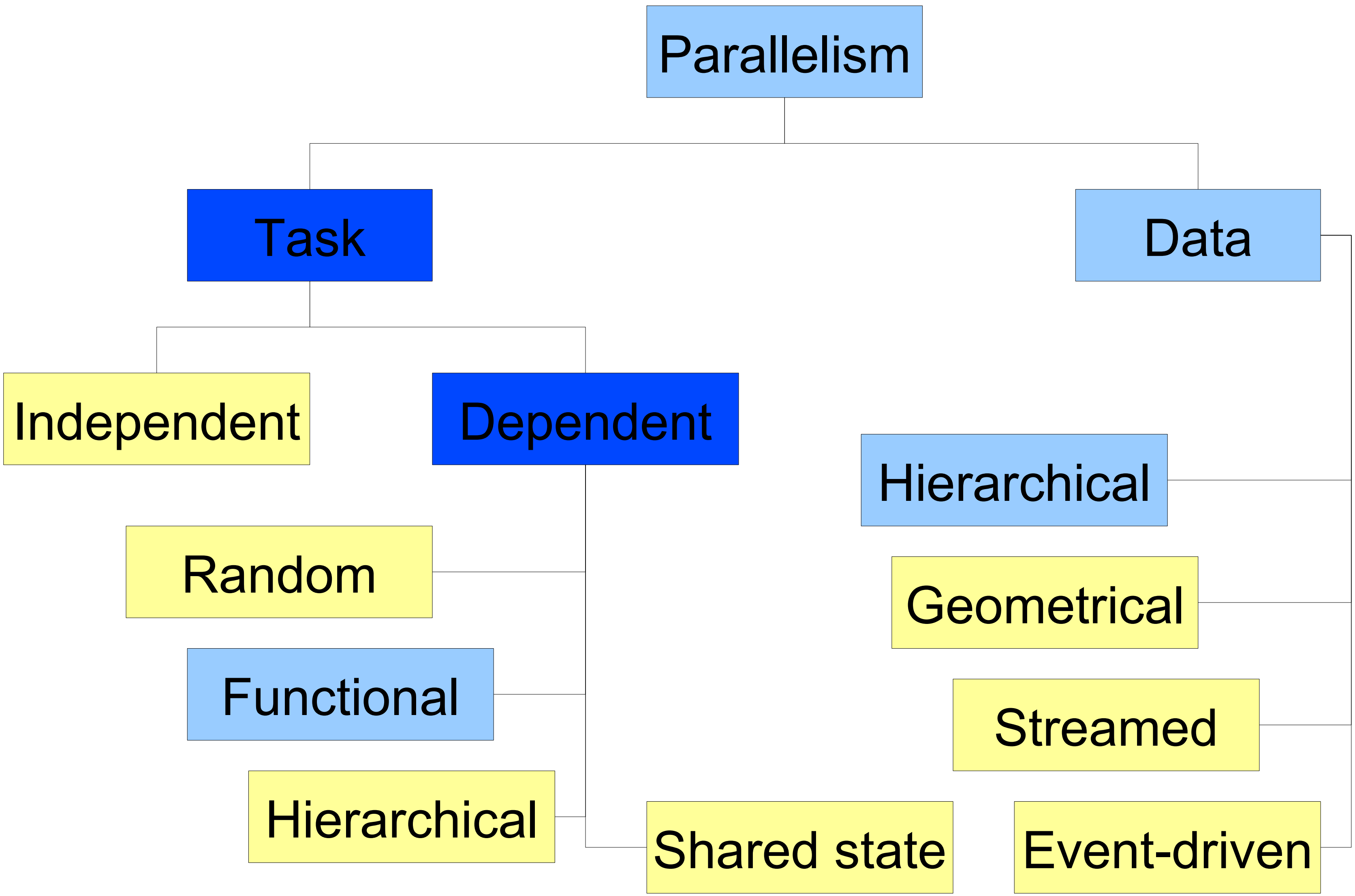
group.task new Callable<V>() {...}

Independent tasks

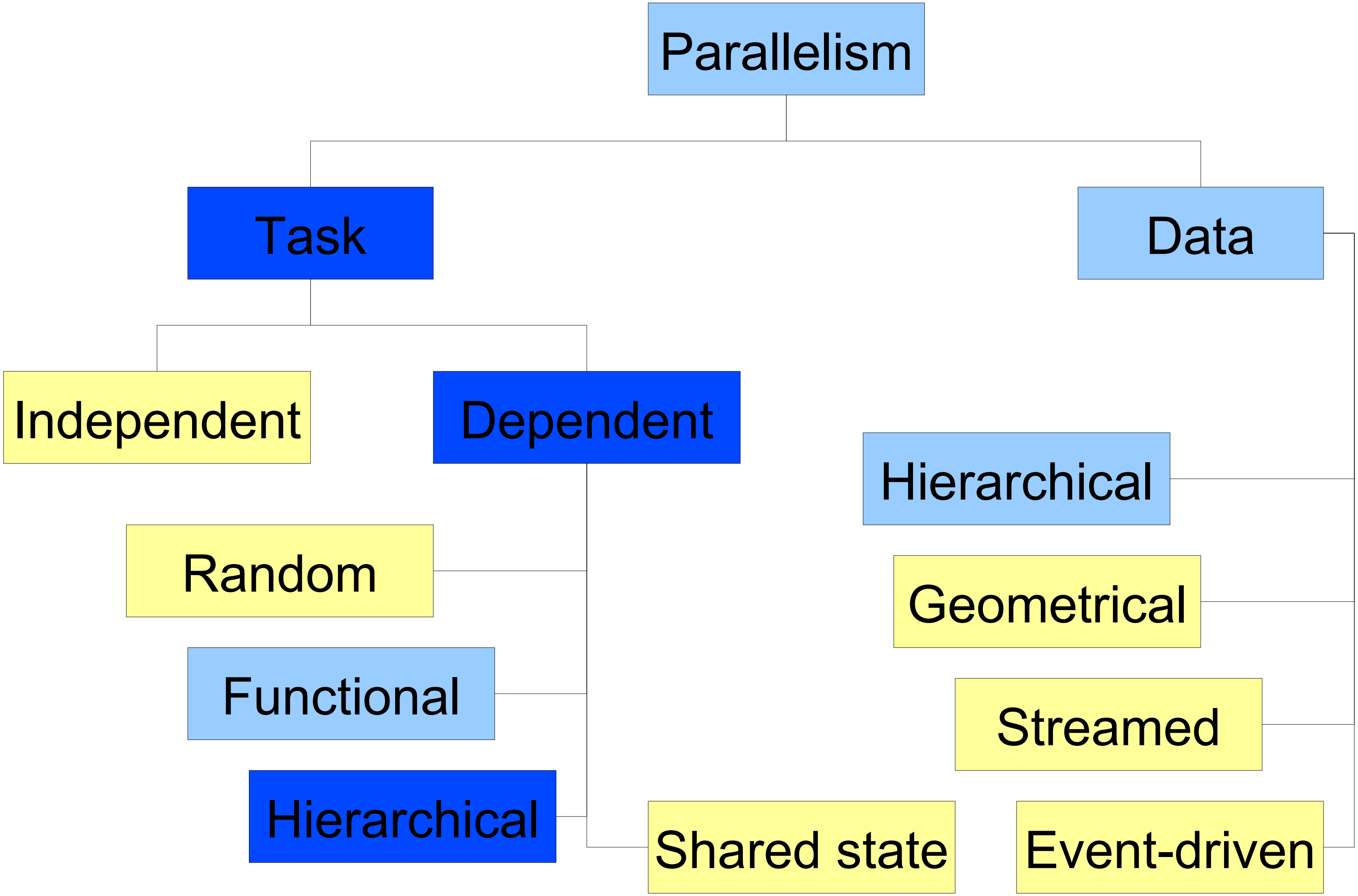
```
def group = new NonDaemonPGroup(10)

submissions.each {form →
    group.task {
        form.process()
    }
}
```

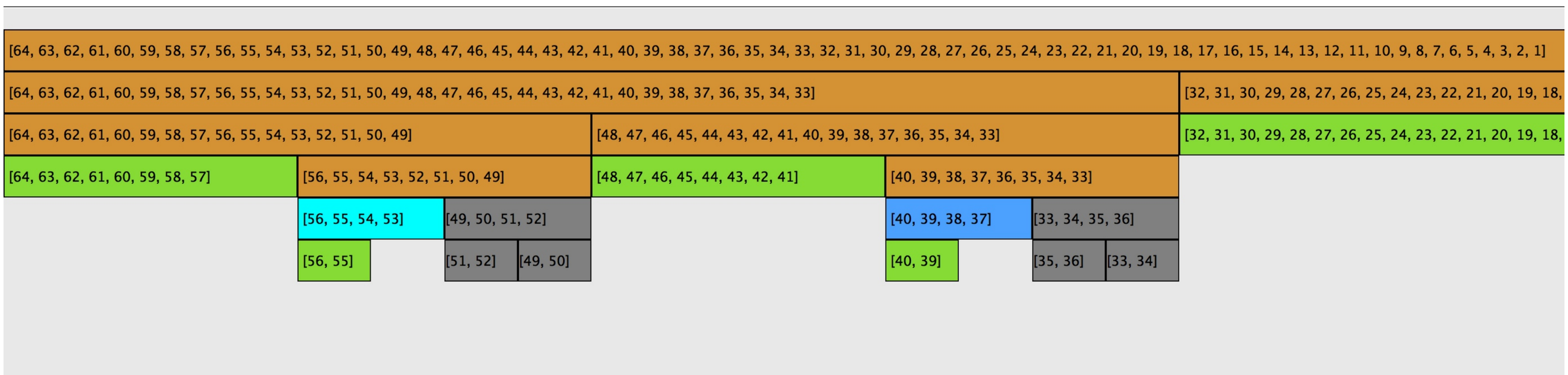
Dependent tasks



Dependent tasks

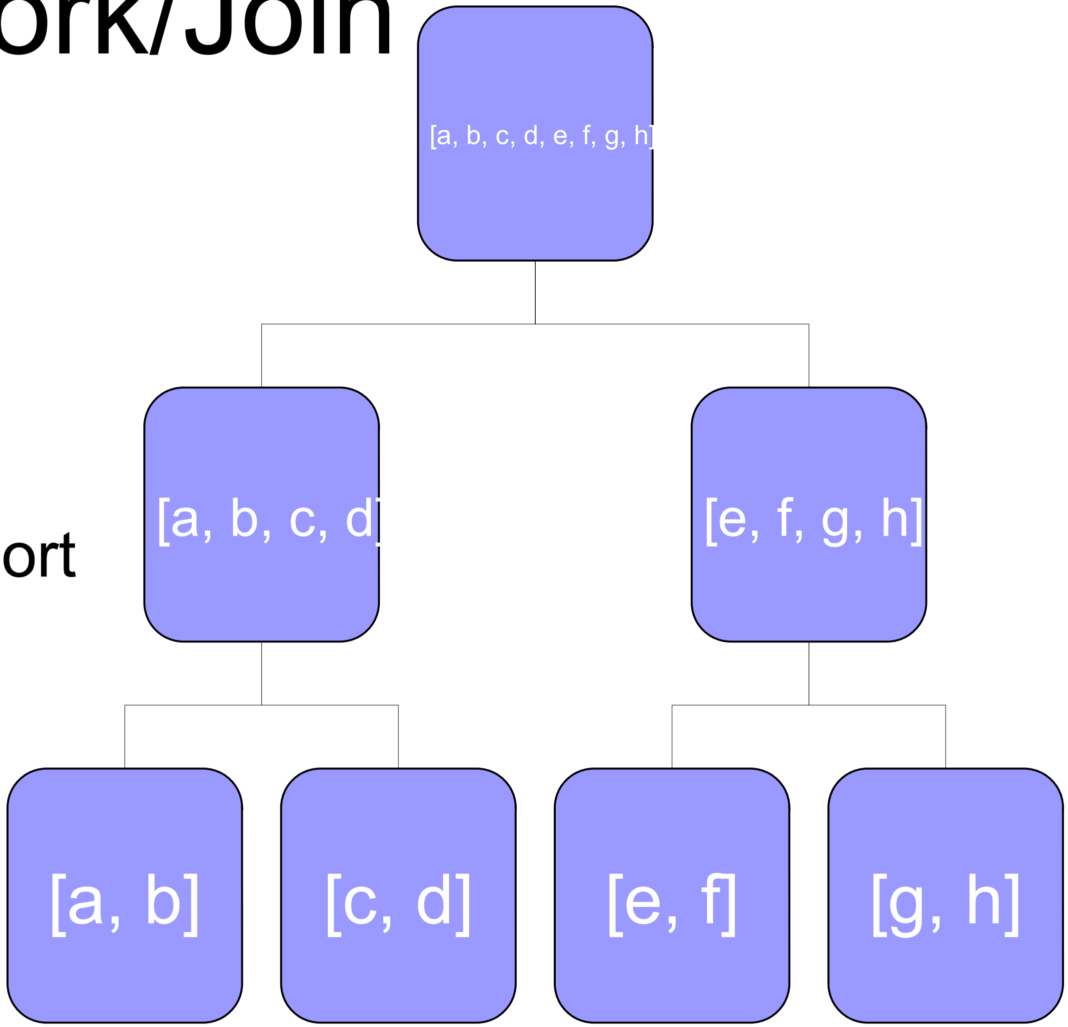


Hierarchical decomposition



Fork/Join

- Solve hierarchical problems
  - Divide and conquer
- Merge sort, Quick sort
- Tree traversal
- File scan / search
- …

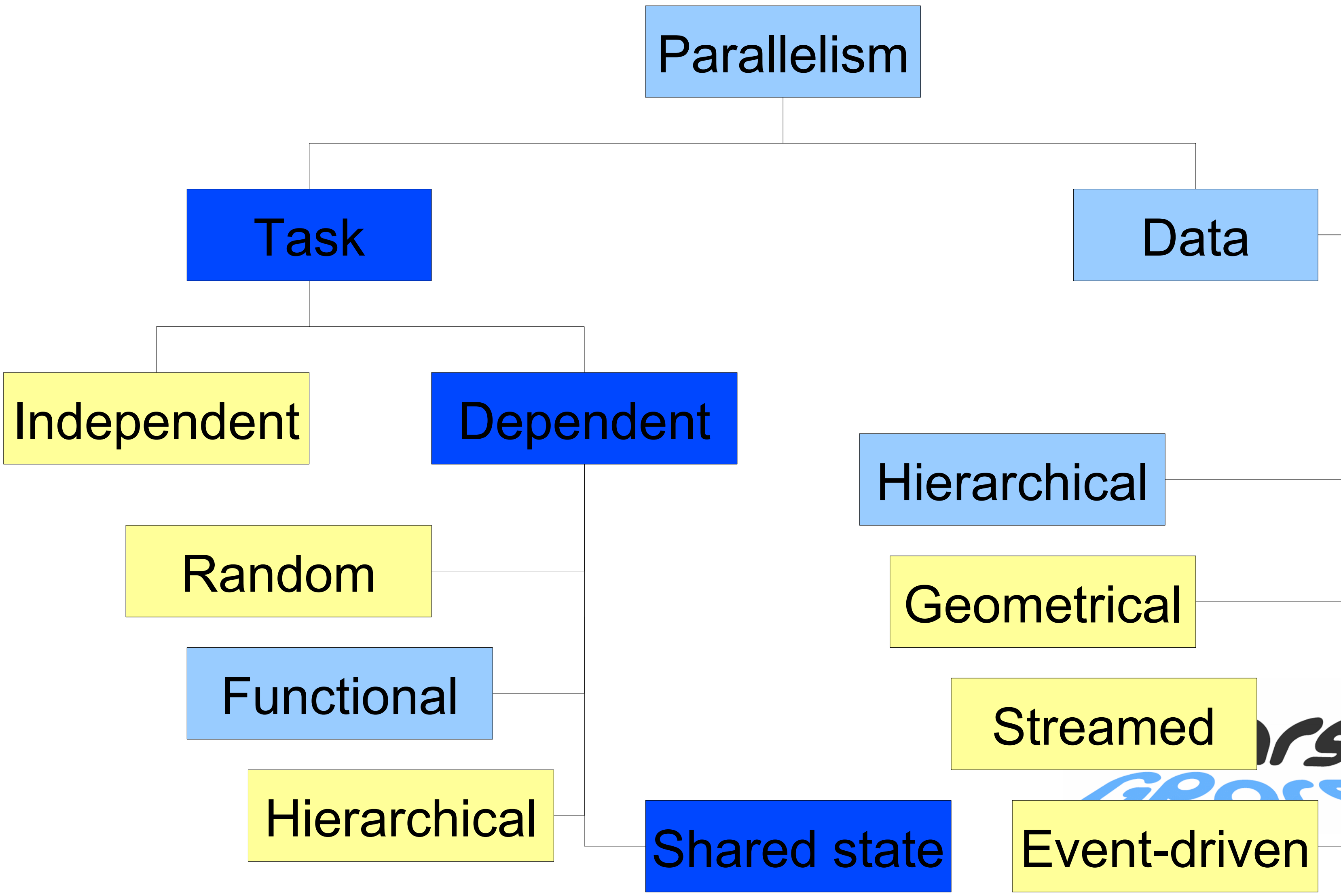


Fork/Join (GPars)

```
{currentDir ->
    long count = 0;
    currentDir.eachFile {
        if (it.isDirectory()) {
            forkOffChild it
        } else {
            count++
        }
    }
    return count + childrenResults.sum(0)
}
```

Waits for children without blocking the thread!

State sharing



State sharing

```
List registrations = []
submissions.each {form →
    group.task {
        if (form.process().valid) {
            registrations << form
        }
    }
}
```

State sharing

Needs protection

```
List registrations = []
submissions.each {form →
    group.task {
        if (form.process().valid) {
            registrations << form
        }
    }
}
```

Shared Mutable State

Frequently over- or mis-used

When really needed, use

- Locks
- Software Transactional Memory
- Agents

STM (Akka - Scala)

```
atomic {
  .. // do something within a transaction
}

atomic(maxNrOfRetries) { .. }
atomicReadOnly { .. }

atomically {
  .. // try to do something
} orElse {
  .. // if tx clash; try do do something else
}
```

Sample taken from Akka documentation - http://doc.akkasource.org/stm

Persistent Data Structures

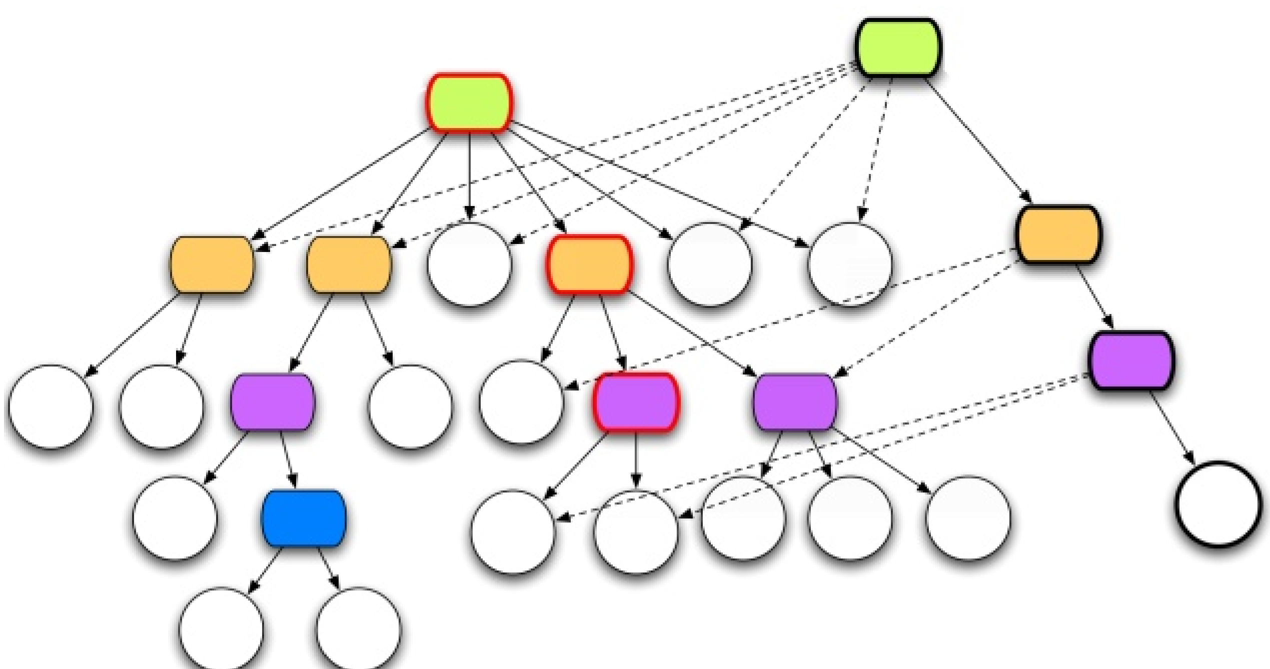
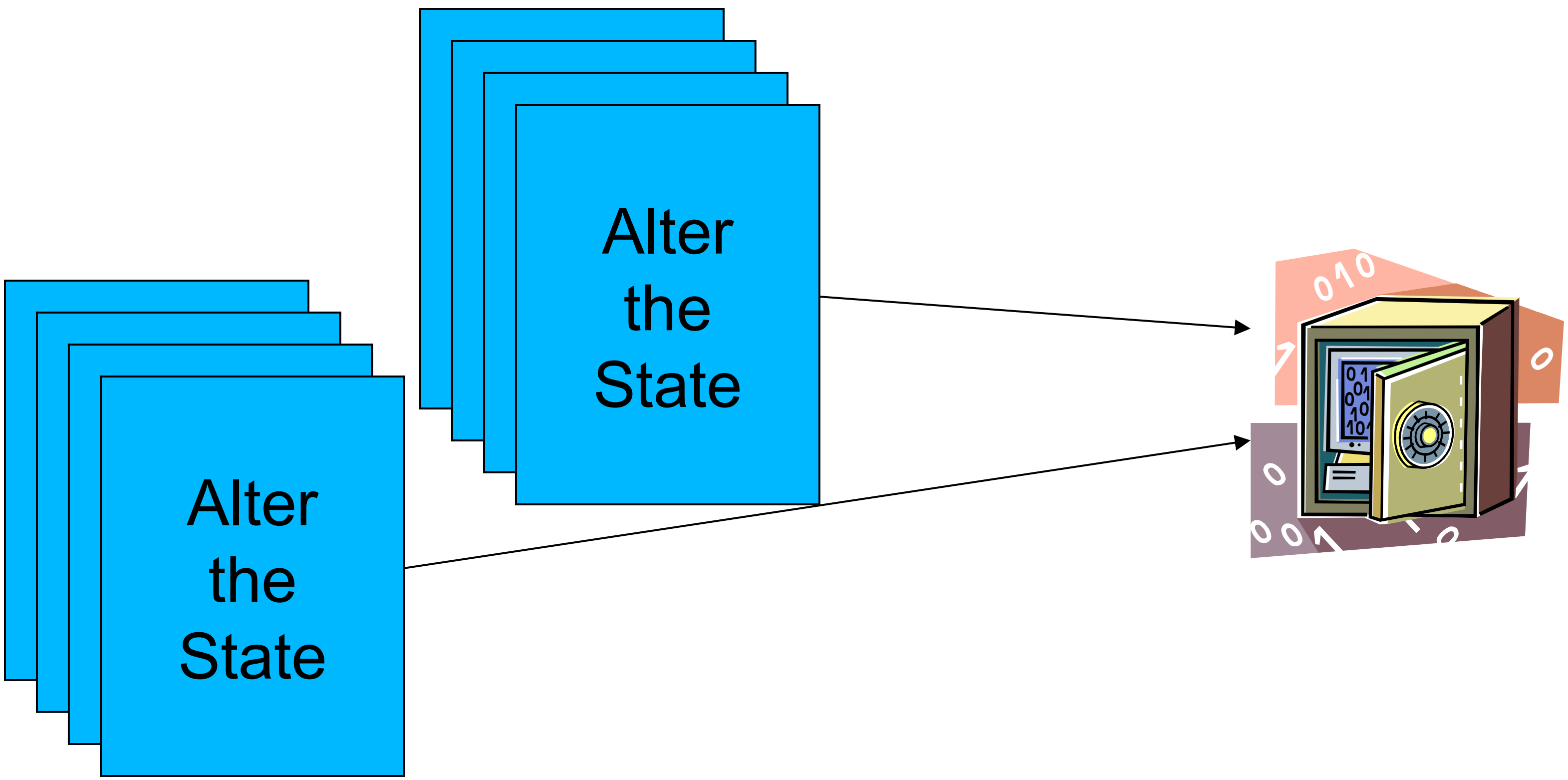


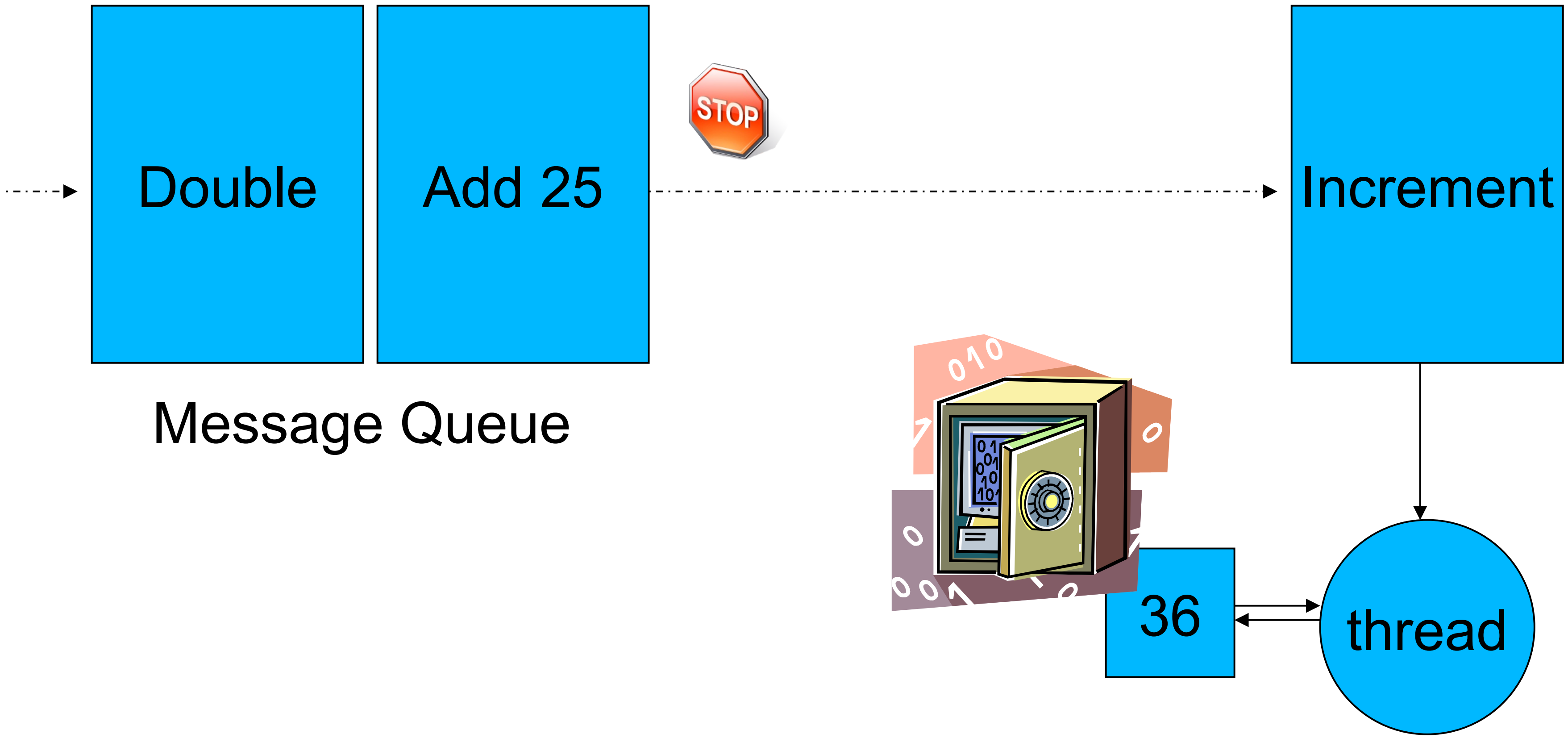
Illustration taken from Rich Hickey's presentation. Copyright Rich Hickey 2009

Agent

Lock Shared Mutable State in a Safe



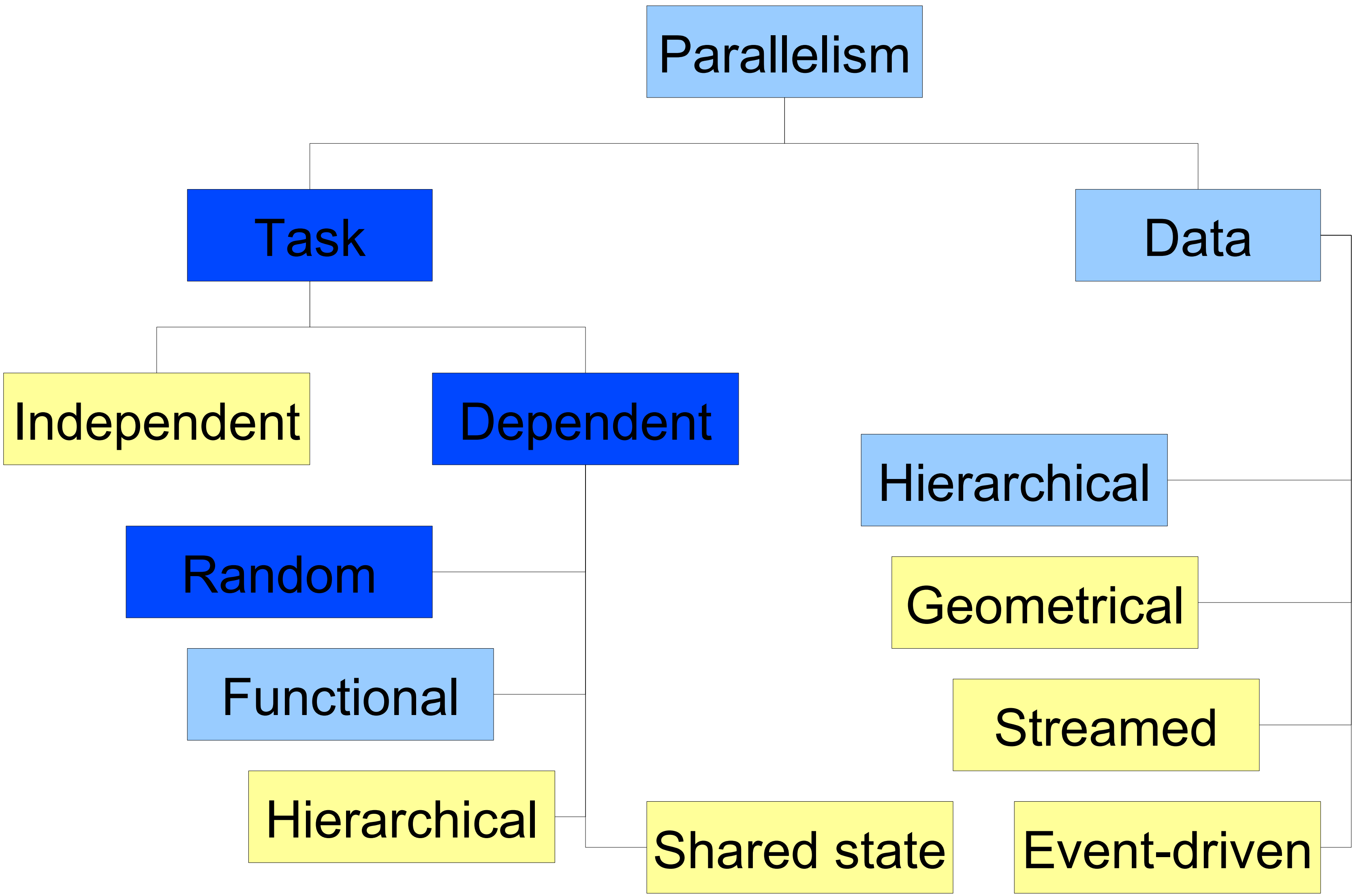
Agent inside



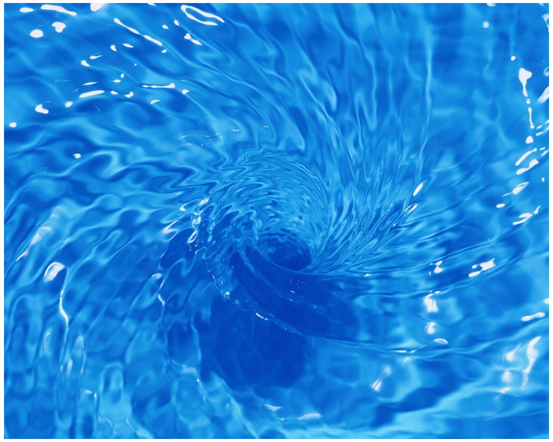
Sharing through agents

```
Agent registrations = new Agent( [] )
submissions.each {form →
    task {
        if (form.process().valid) {
            registrations.send {it << form}
        }
    }
}
```

Random task dependency



Dataflow Concurrency

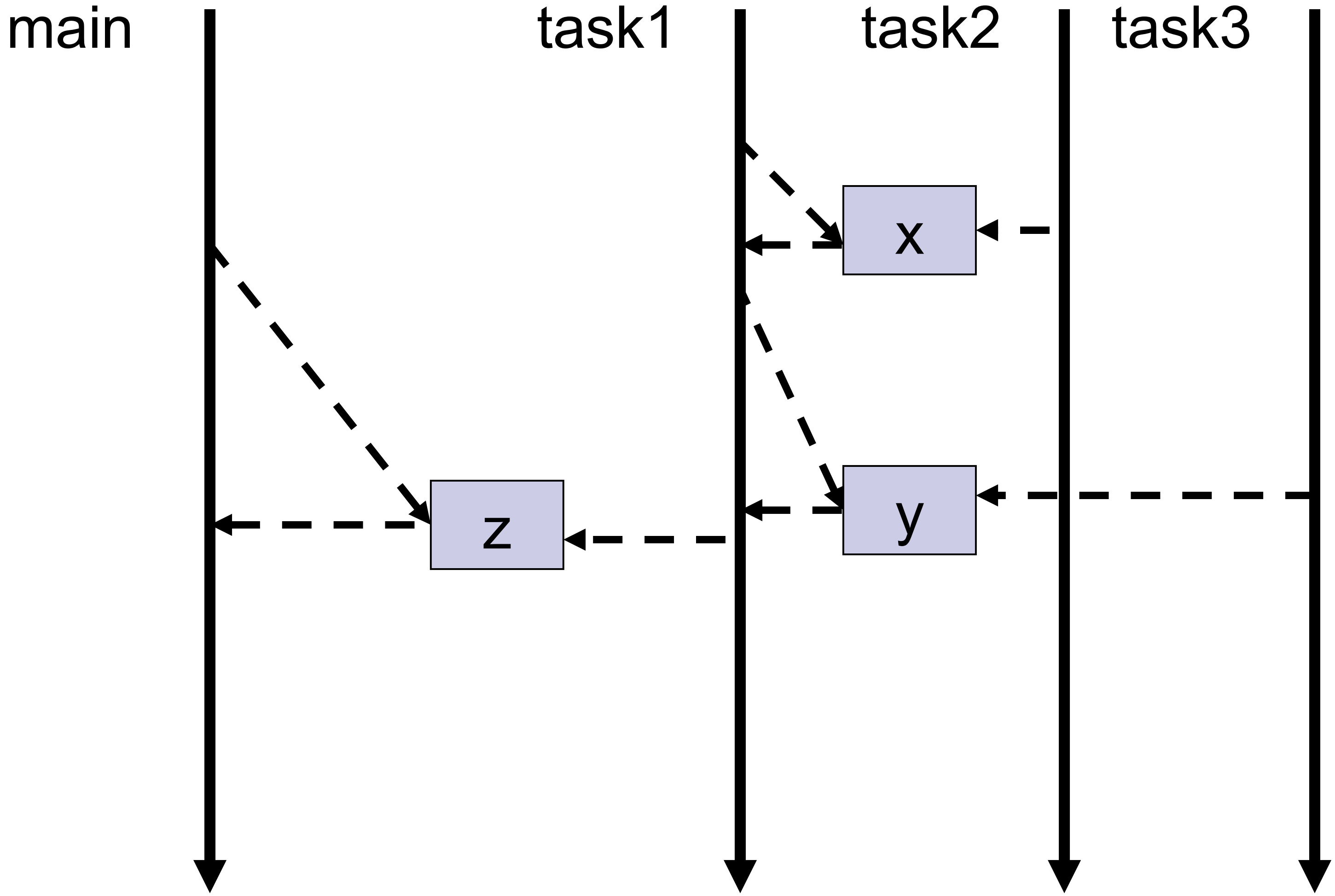


No race-conditions

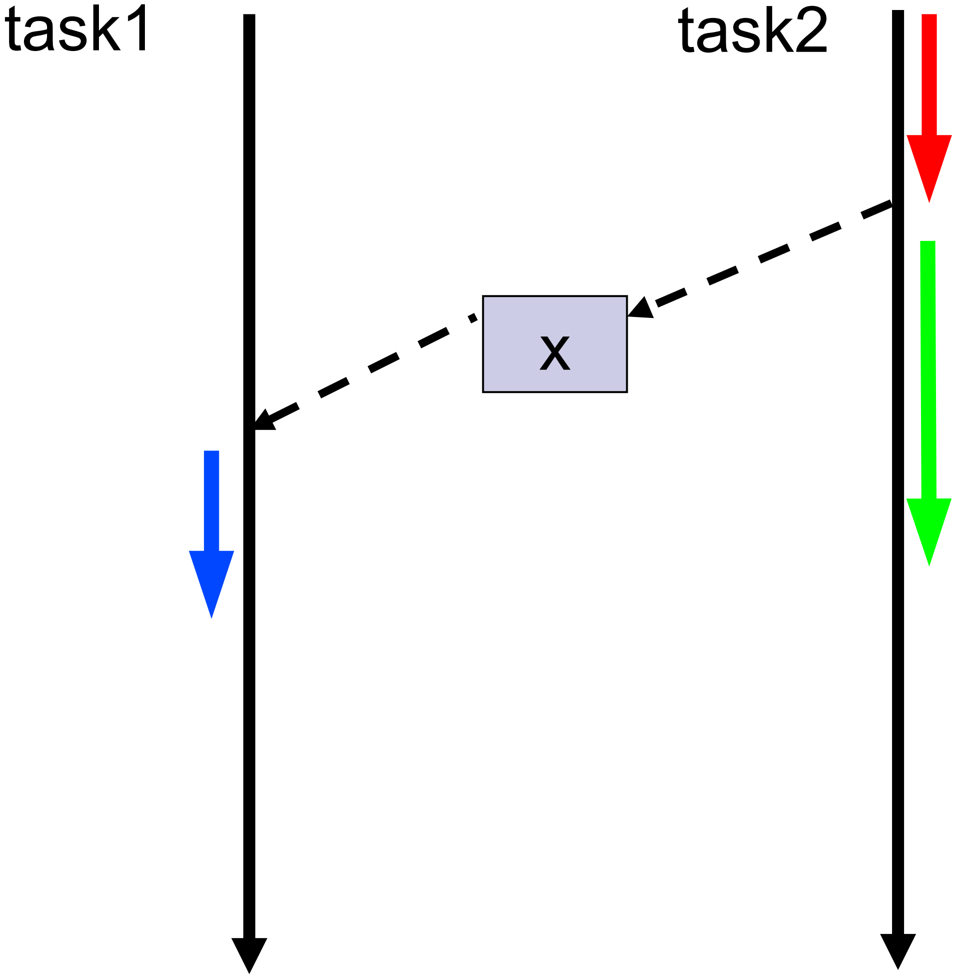
No live-locks

Deterministic deadlocks

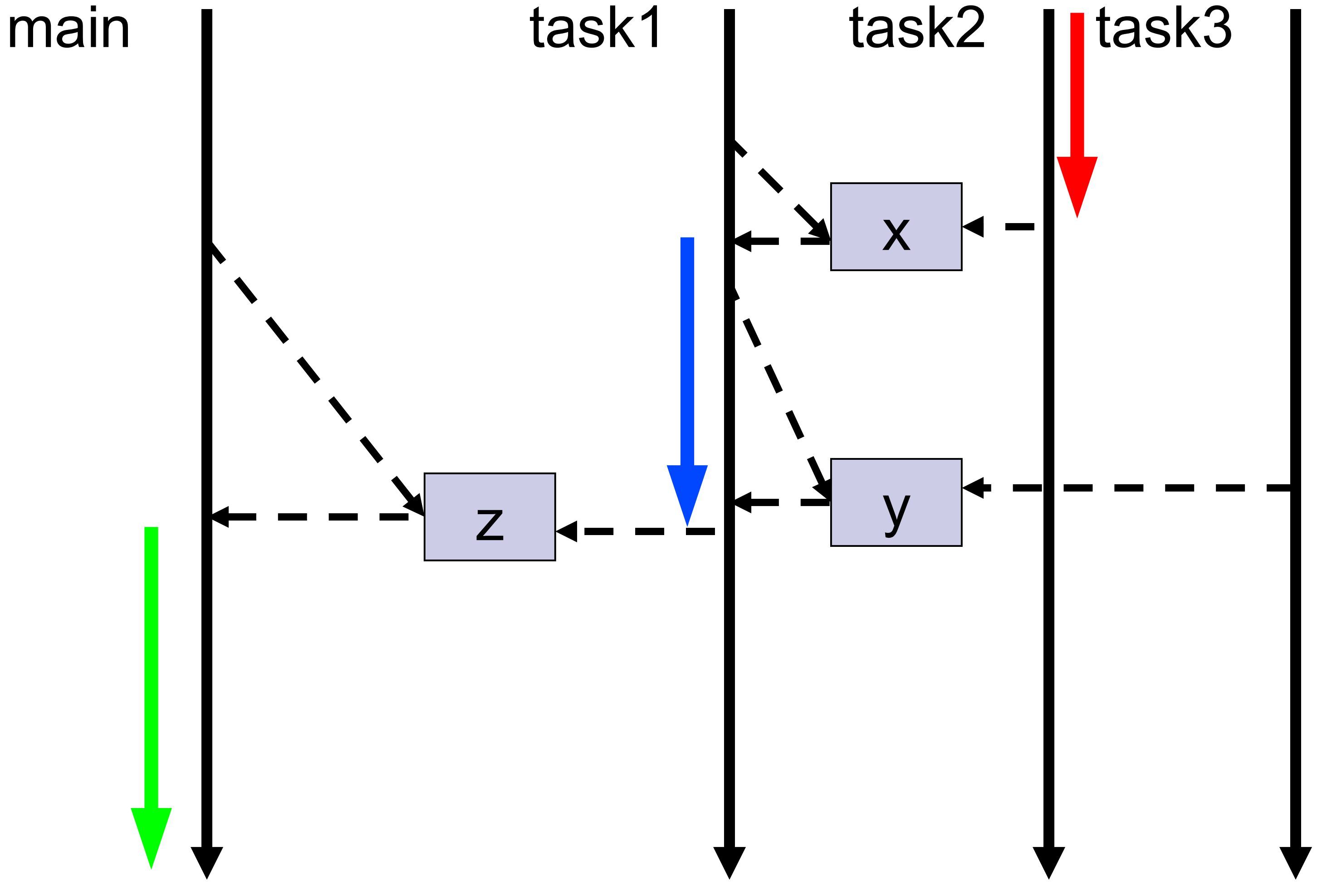
Dataflow Variables / Promises



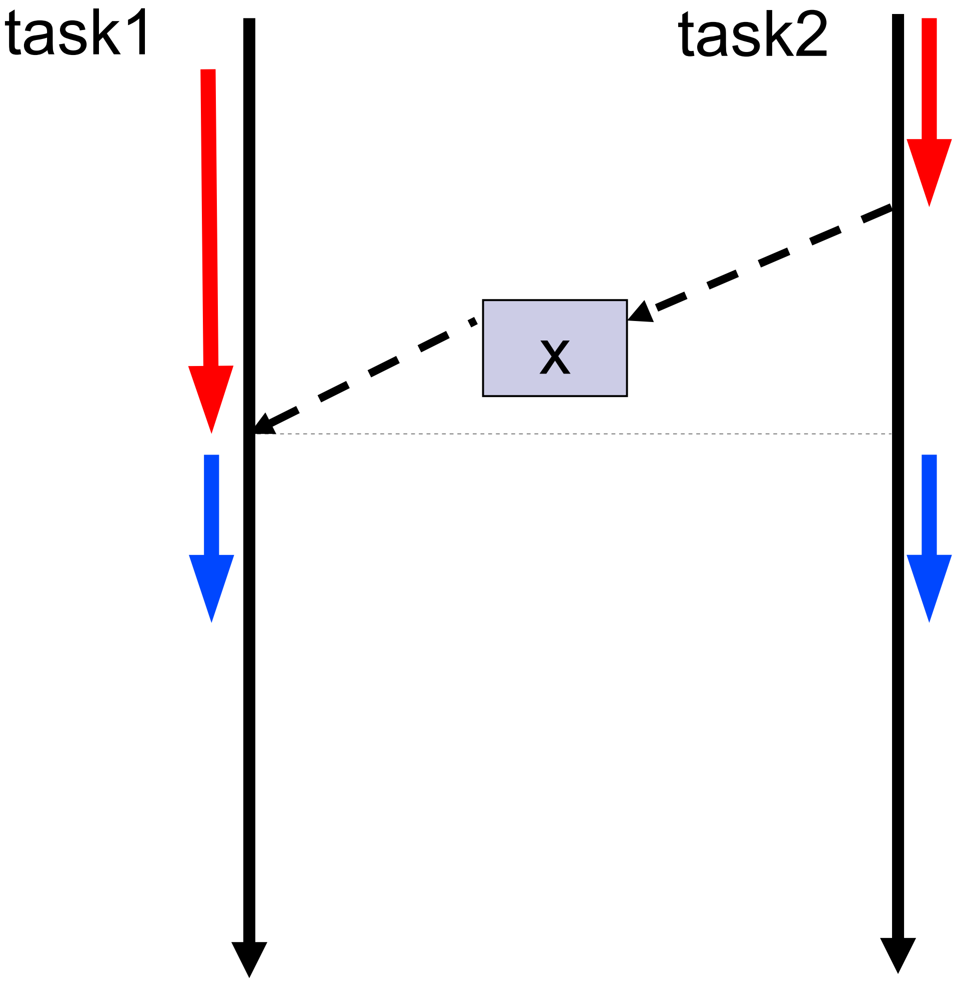
Dataflow Variables / Promises



Dataflow Variables / Promises



Synchronous Variables



Promises to exchange data

```
task { z << x.val + y.val }
task { x << 10 }
task {
    println ”I am task 3”
    y << 5
}
assert 15 == z.val
```

Glue tasks together

```
Promise c1 = task {compile(module1)}
Promise c2 = task {compile(module2)}
```

Glue tasks together

Promise c1 = task {compile(module1)}

Promise c2 = task {compile(module2)}

Promise j1 = c1.then {jar it}

Promise j2 = c2.then {jar it}

Glue tasks together

```
Promise c1 = task {compile(module1)}
Promise c2 = task {compile(module2)}

Promise j1 = c1.then {jar it}
Promise j2 = c2.then {jar it}
whenAllBound(j1, j2) {m1, m2 → deploy(m1, m2)}
j1.then {pushToRepo it}
```

Glue tasks together

```
Promise c1 = task {compile(module1)}
Promise c2 = task {compile(module2)}

Promise j1 = c1.then {jar it}
Promise j2 = c2.then {jar it}
whenAllBound(j1, j2) {m1, m2 → deploy(m1, m2)}
j1.then {pushToRepo it}
iWillSendEmailWhenJarred(j1)
```

Chaining promises

```
def h1 = download('url') then {text → text.trim()} then hash
```

Chaining promises

```
def h1 = download('url') then {text → text.trim()} then hash
```

```
def h1 = download('url') | {text → text.trim()} | hash
```

Error handling

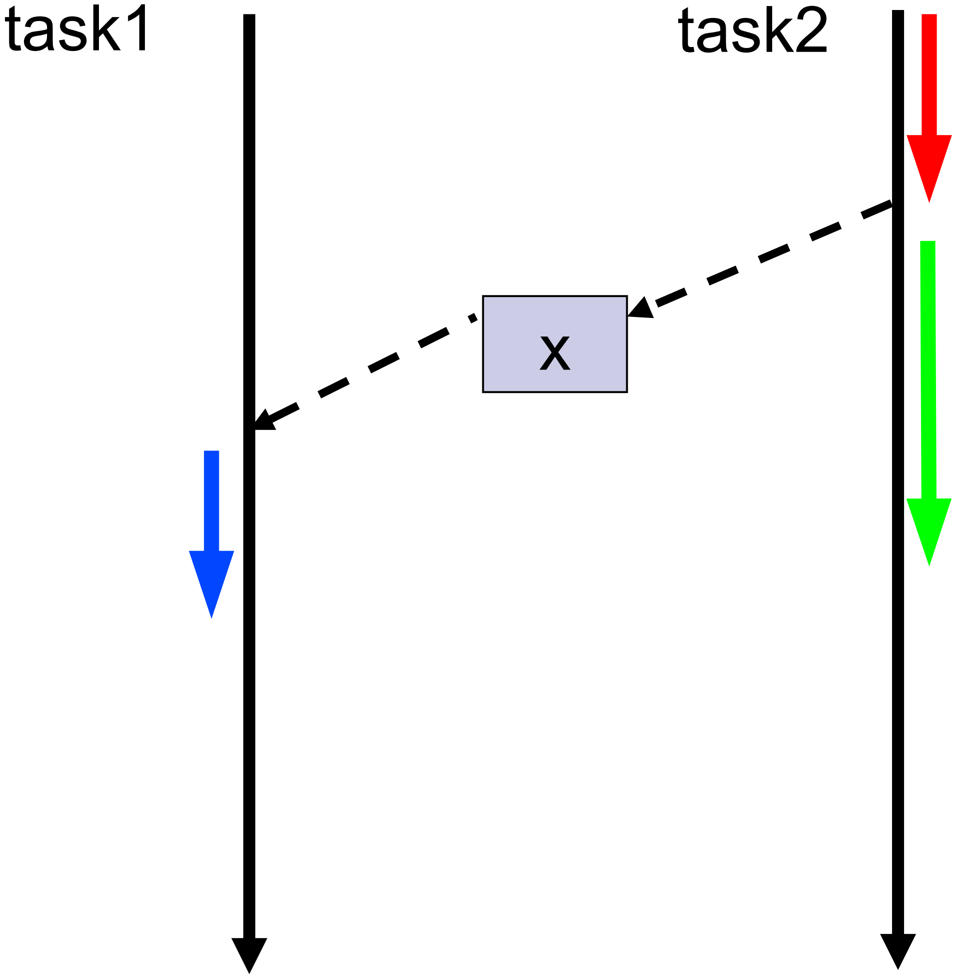
```
url.then(download)
   .then(calculateHash)
   .then(formatResult)
   .then(printResult, printError)
   .then(sendNotificationEmail);
```

Lazy promises

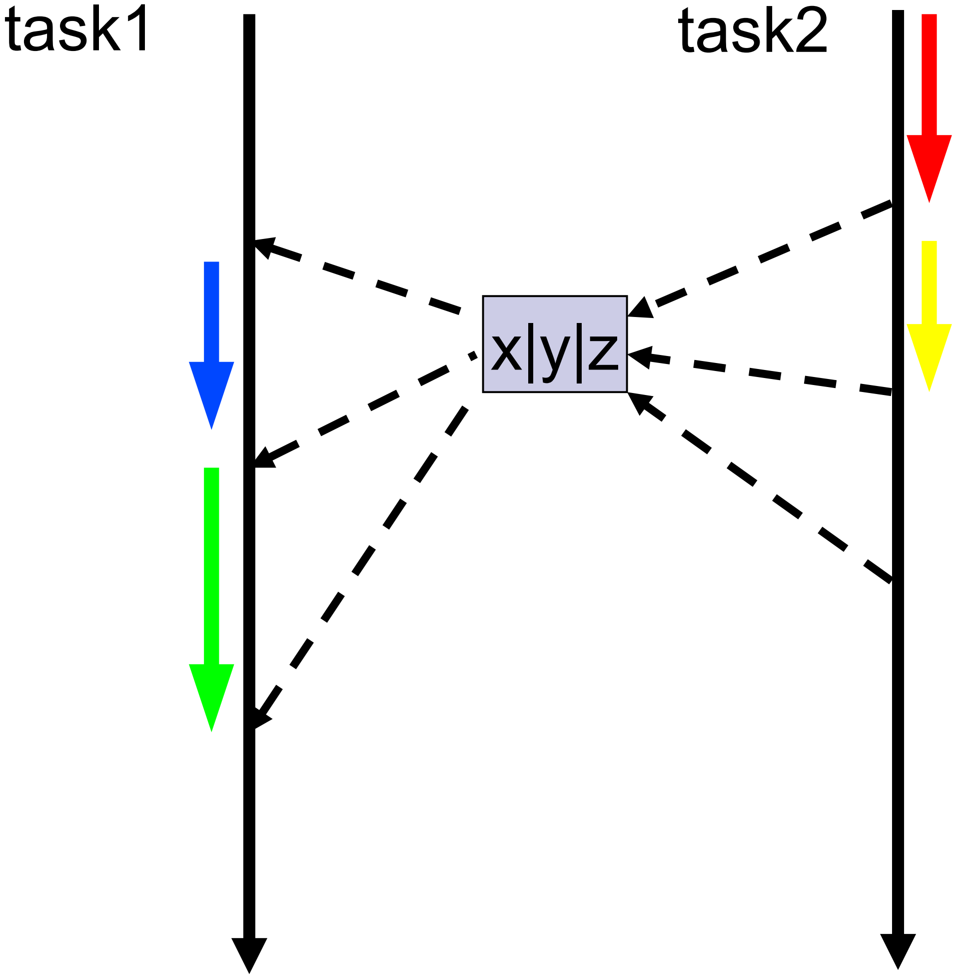
Only calculated when needed the first time

```
def mostPopularLang = new LazyDataflowVariable({->
        return longLastingCalculation()
    }
})
```

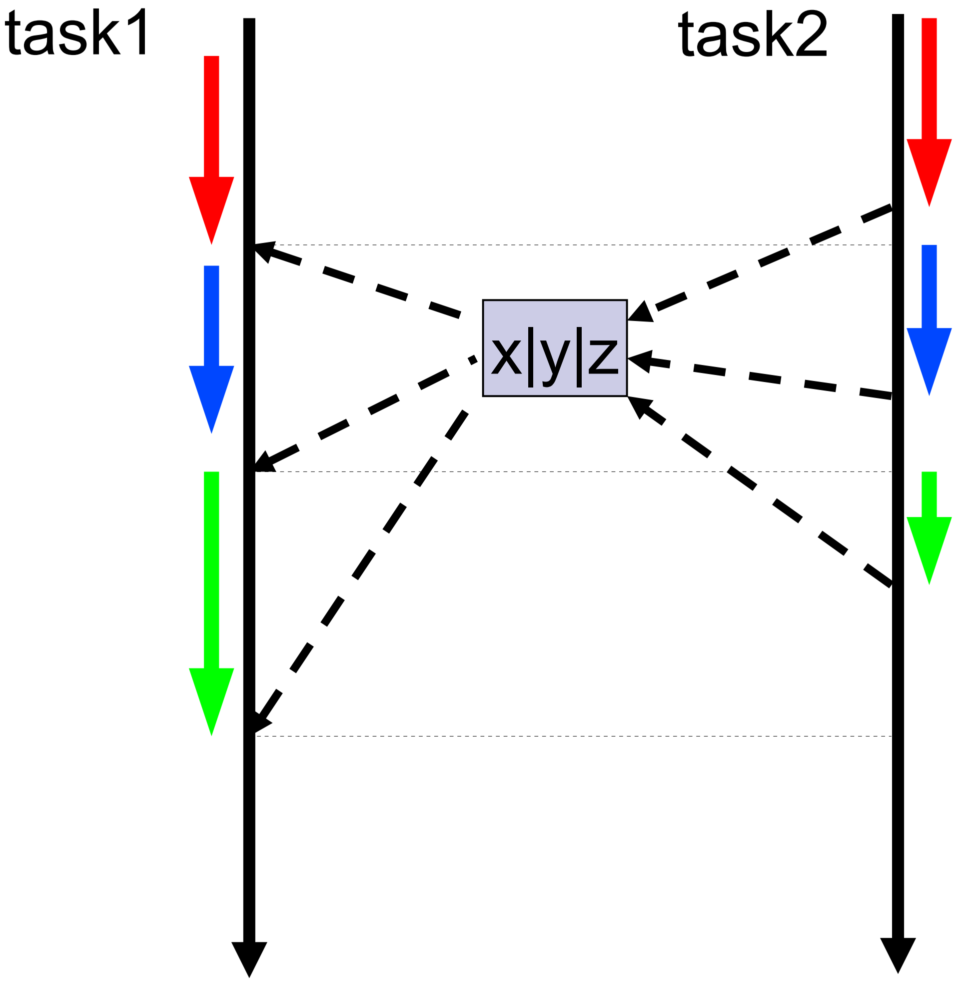
Dataflow Variables / Promises



Dataflow Channels



Synchronous Channels



Async progress indication

```
List<Promise> forms=submissions.collect {form →
    group.task {
        def result = form.process()
        progressQueue << 1
        if (result.valid) {
            return form
        }
    }
}
```

Async result reporting

```
submissions.each {form →
    group.task {
        if (form.process().valid) queue << form
    }
}
```

Channel Selection

```
Select alt = group.select(validForms, invalidForms)

SelectResult selectResult = alt.select()  //alt.prioritySelect()

switch (selectResult.index) {
        case 0: registrations << selectResult.value; break
        case 1: ...
}
```

Tasks as processes

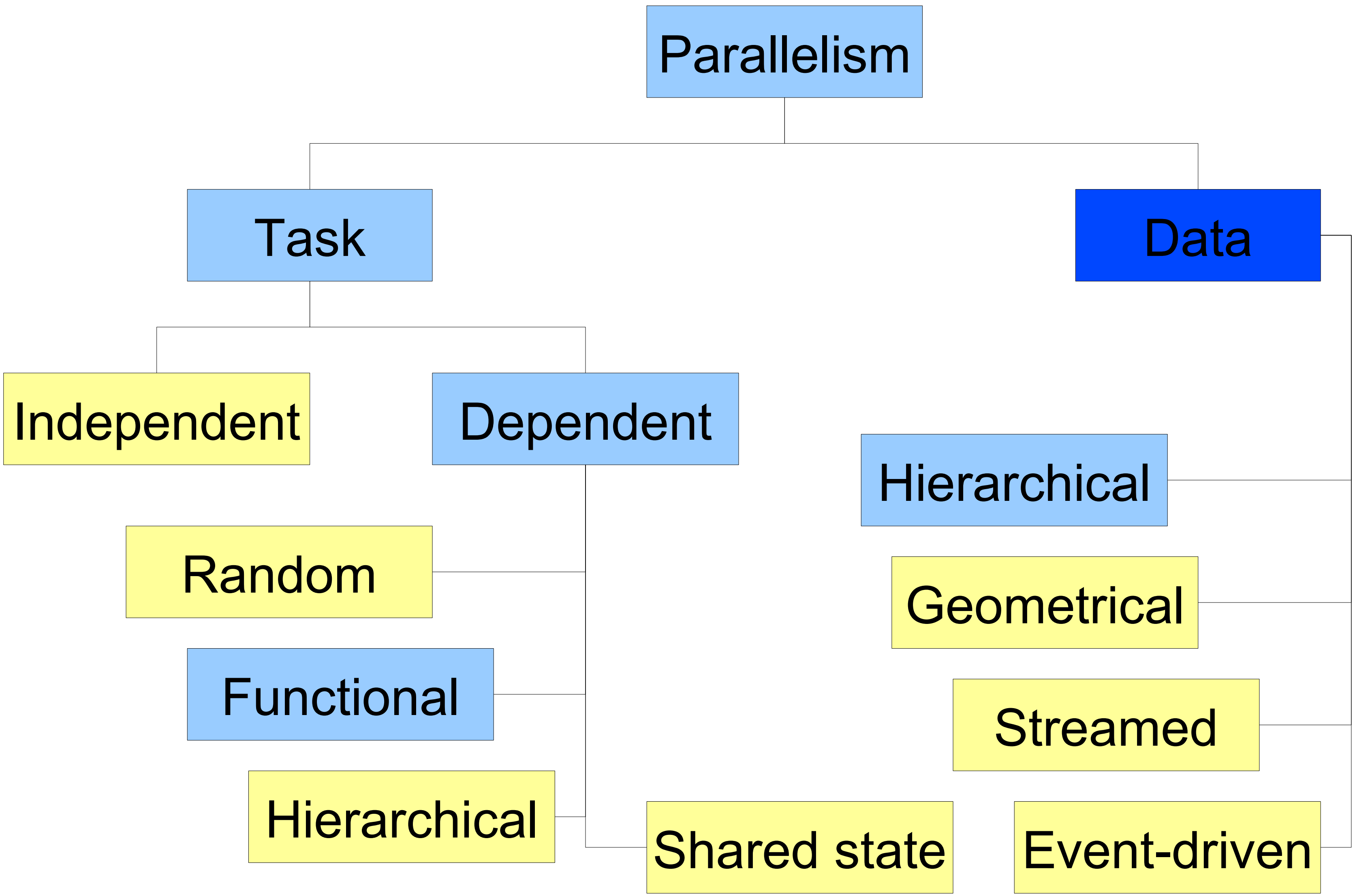
```
group.task {
    doStuff()
    logChannel << 'initialized'
    def result = doWork(workQueue.val)
    if (result.isError) errors << result
    else results << result
    logChannel << 'finished'
}
```

A CSP flavour

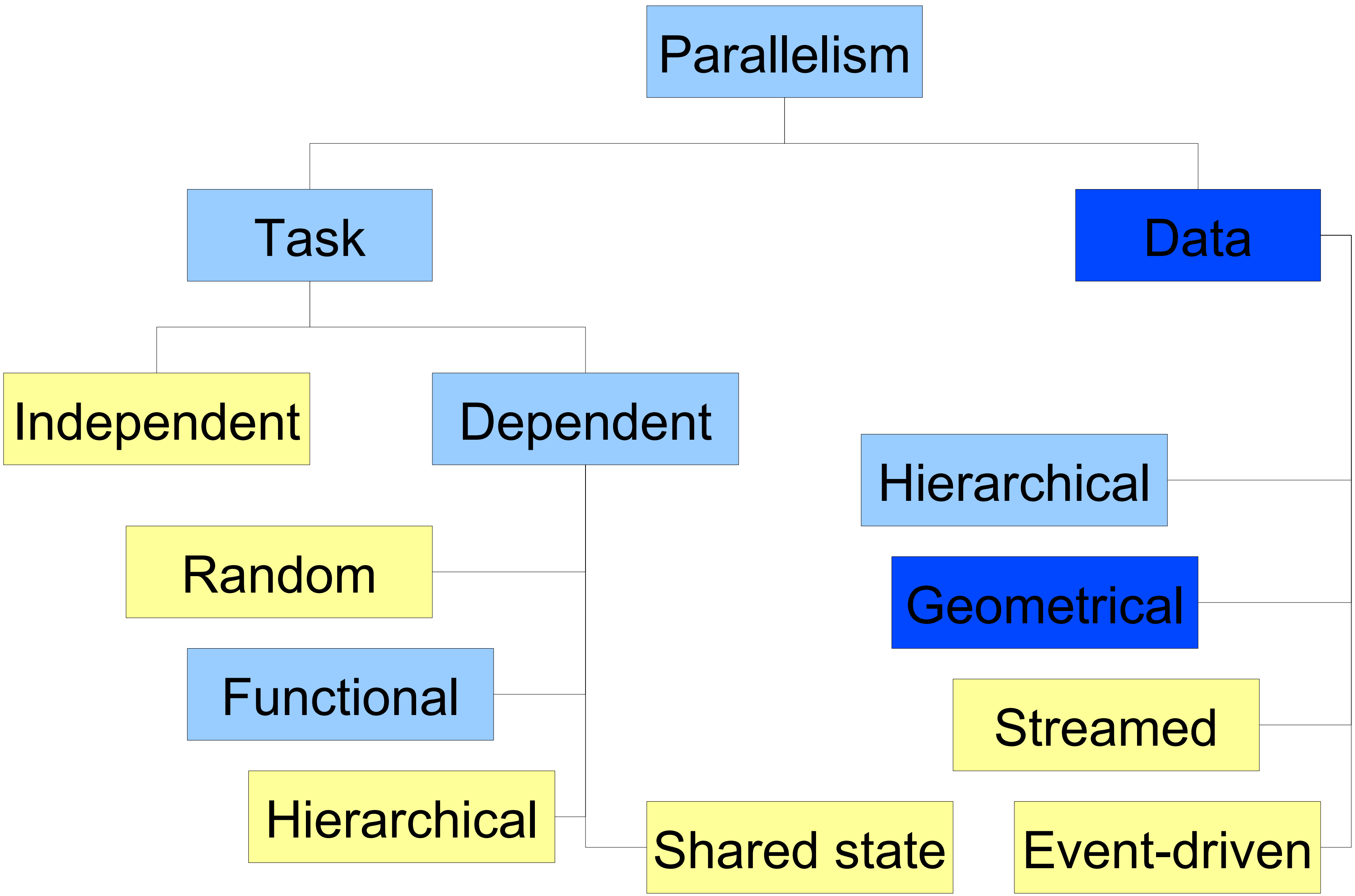
Communicating Sequential Processes

Focus on composable processes more than on data

Data parallelism

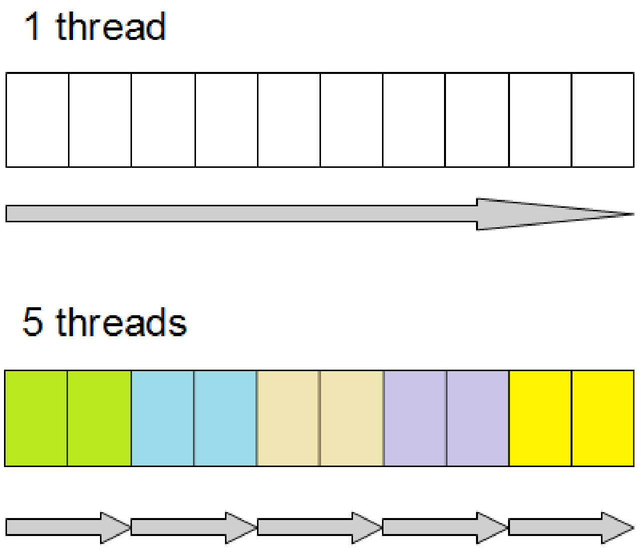


Data parallelism



Geometric decomposition

```
images.eachParallel {it.process()}
documents.sumParallel()
candidates.maxParallel {it.salary}.marry()
```

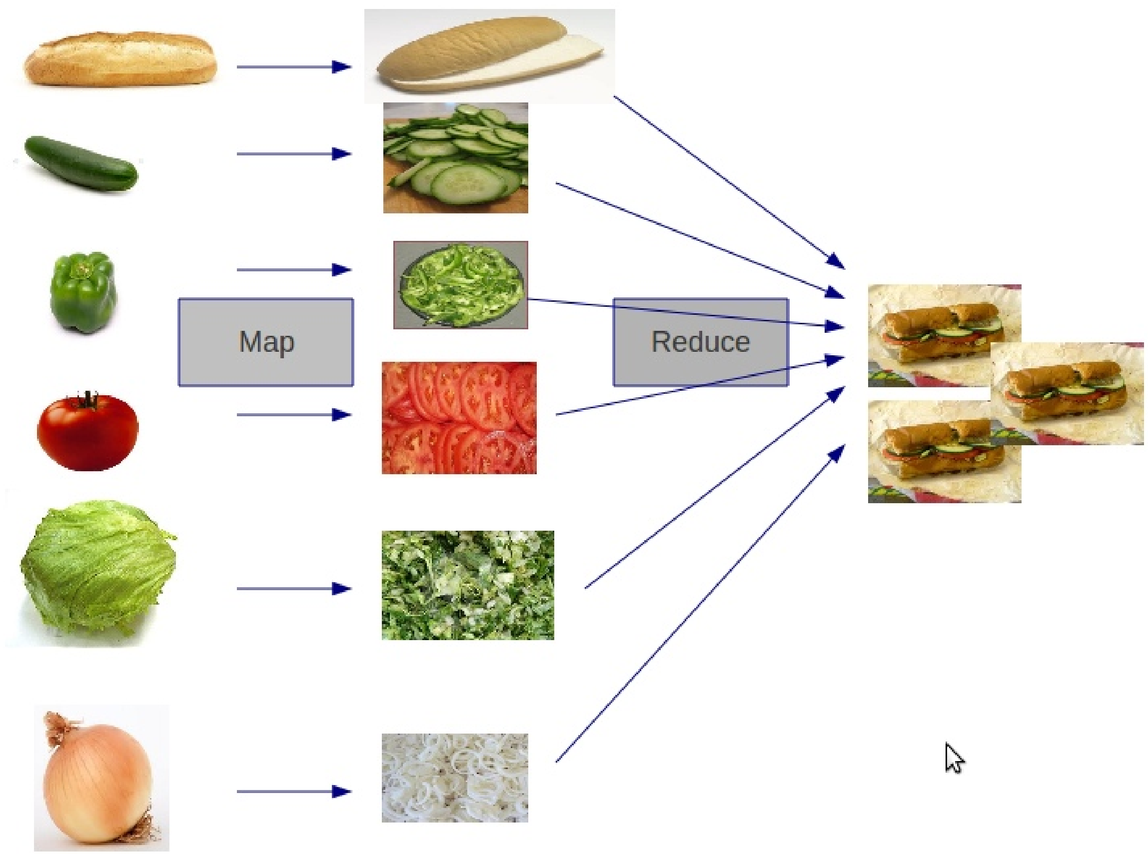


Geometric decomposition

```
registrations = submissions
        .collectParallel { form -> form.process()}
        .findAllParallel { it.valid }

registrations = submissions.parallel
        .map { form -> form.process()}
        .filter { it.valid }.collection
```

Map - reduce



Frequent confusion

stackoverflow

Questions | Tags | Users | Badges | Unanswered

parallel quick sort outdone by single threaded quicksort

0

I've been reading , here is the example in the book using futures to implement parallel quick sort.

But I found this function is more than twice slower than the single threaded quick sort function without using any asynchronous facilities in c++ standard library. Tested with g++ 4.8 and visual c++ 2012.

I used 10M random integers to test, and in visual c++ 2012,this function spawned 6 threads in total to perform the operation in my quad core PC.

I am really confused about the performance. Any body can tell me why?

GPU

Improper use 1

```
def accumulator = 0

myCollection.eachParallel {
    accumulator += calculate(it)
}
```

Do not accumulate, map-reduce!

```
def accumulator = myCollection.parallel
                              .map {calculate(it)}
                              .reduce {a, b → a + b}
```

Improper use 2

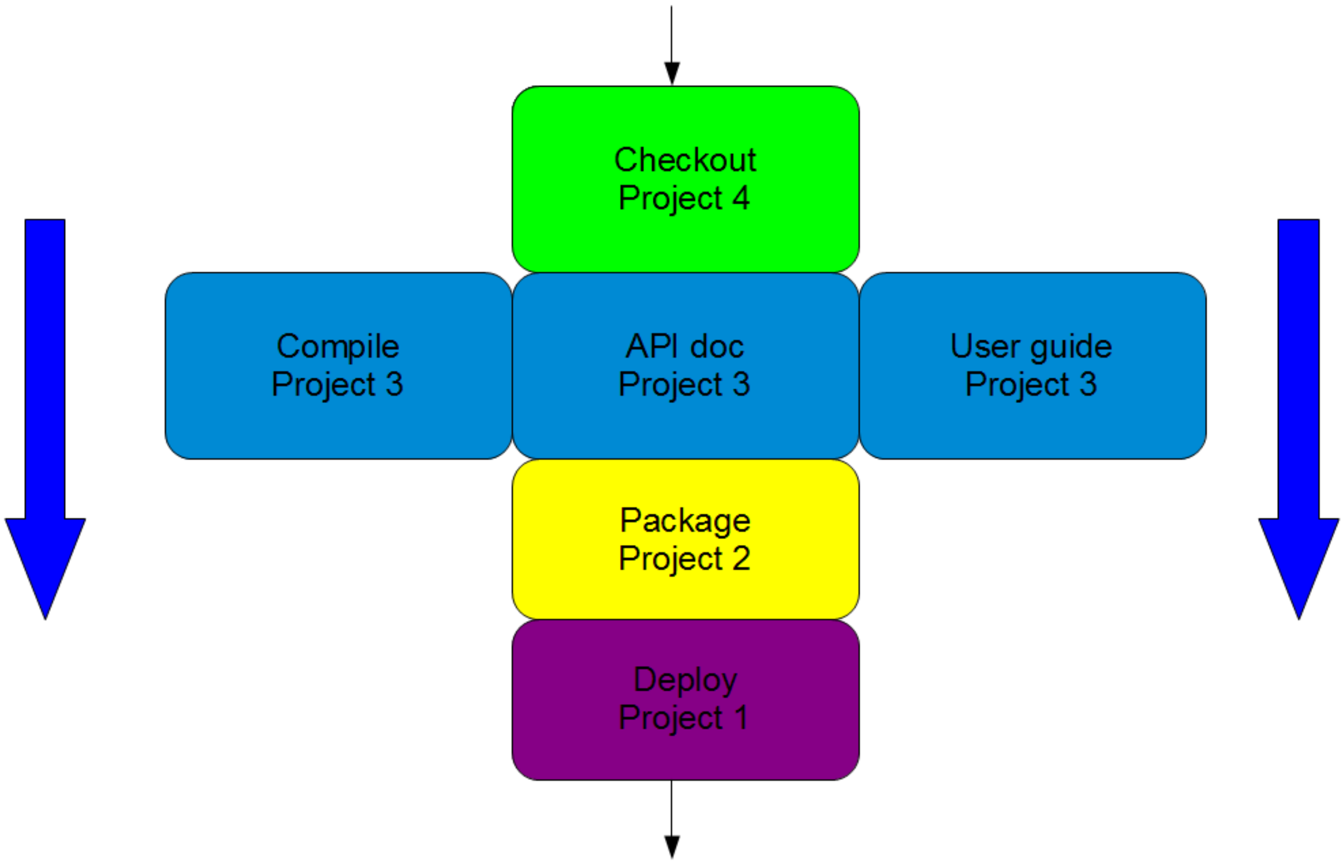
```
new File("/file.txt").withReader{reader ->
    reader.eachParallel {
        def r1 = step1(r)
        def r2 = step2(r1)
        def r3 = step3(r2)
    }
}
```

Unroll iteration

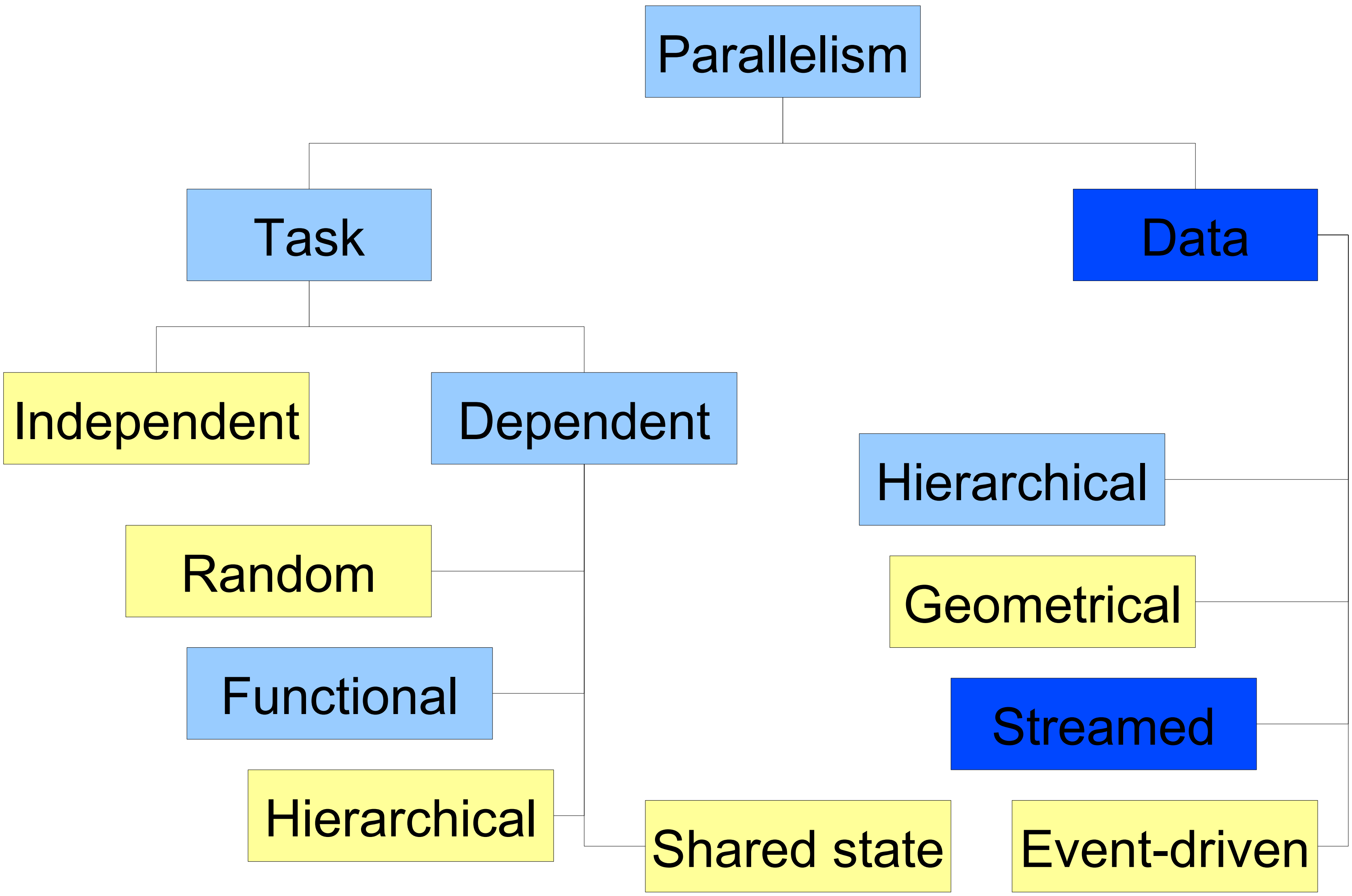
```
def pipeline = data | step1 | step2 | step3

new File("/file.txt").withReader{reader ->
    reader.each {
        data << it
    }
}
```

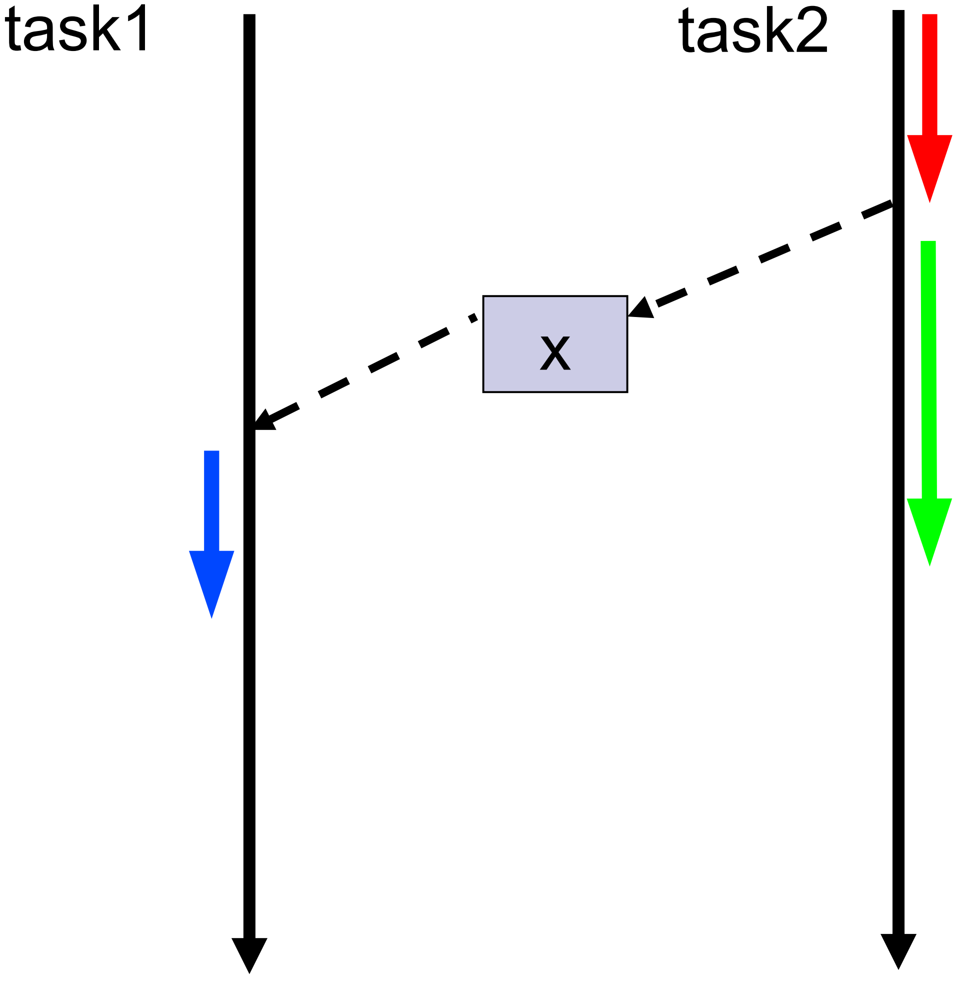
Unroll iteration



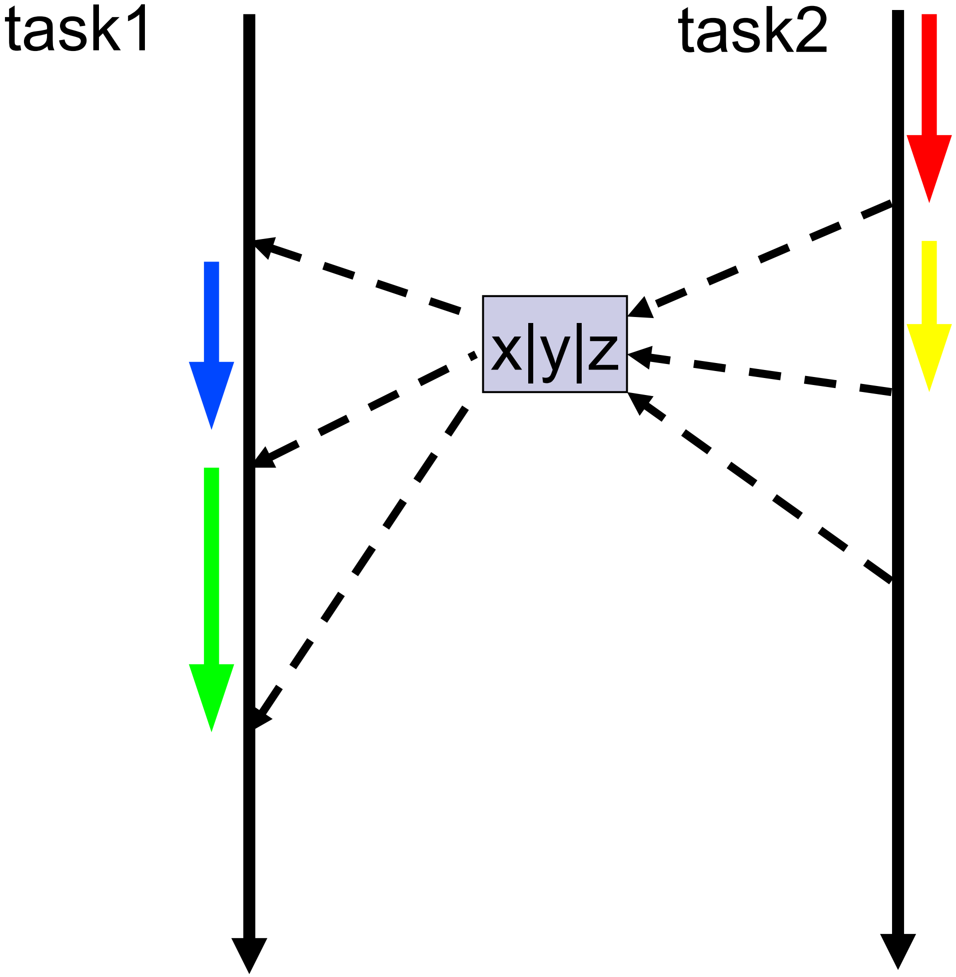
Streamed data



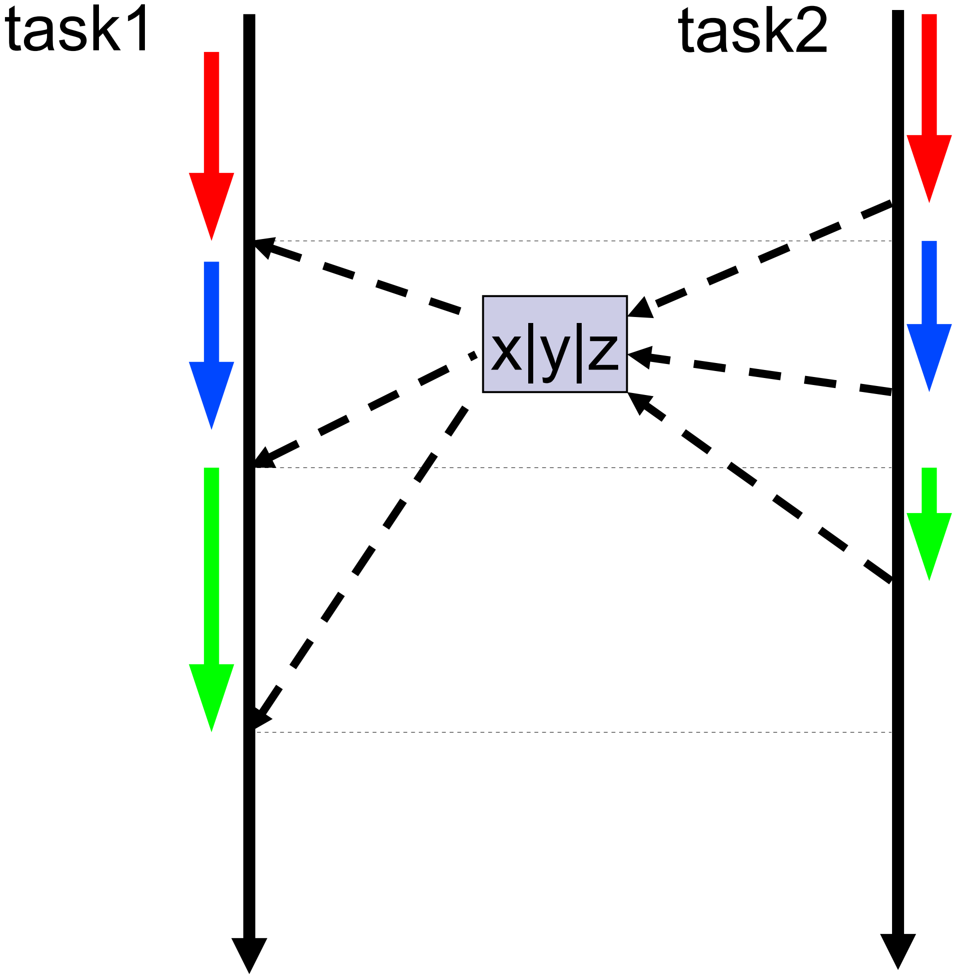
Dataflow Variables / Promises



Dataflow Channels



Synchronous Channels

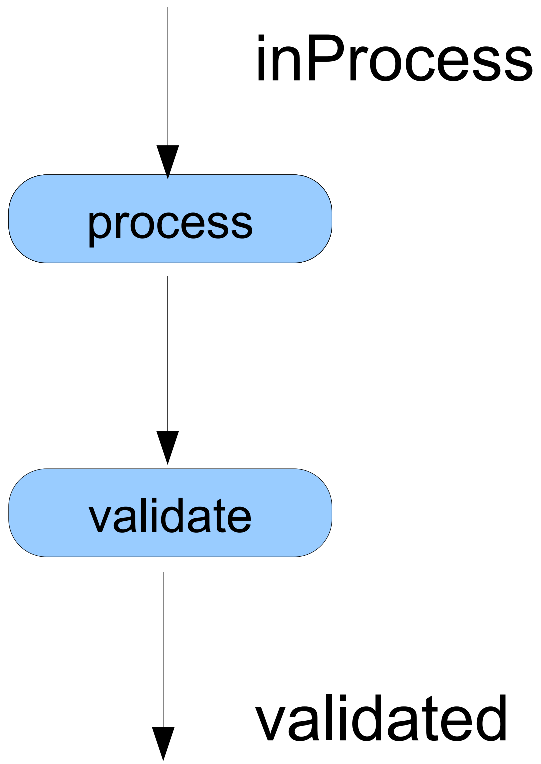


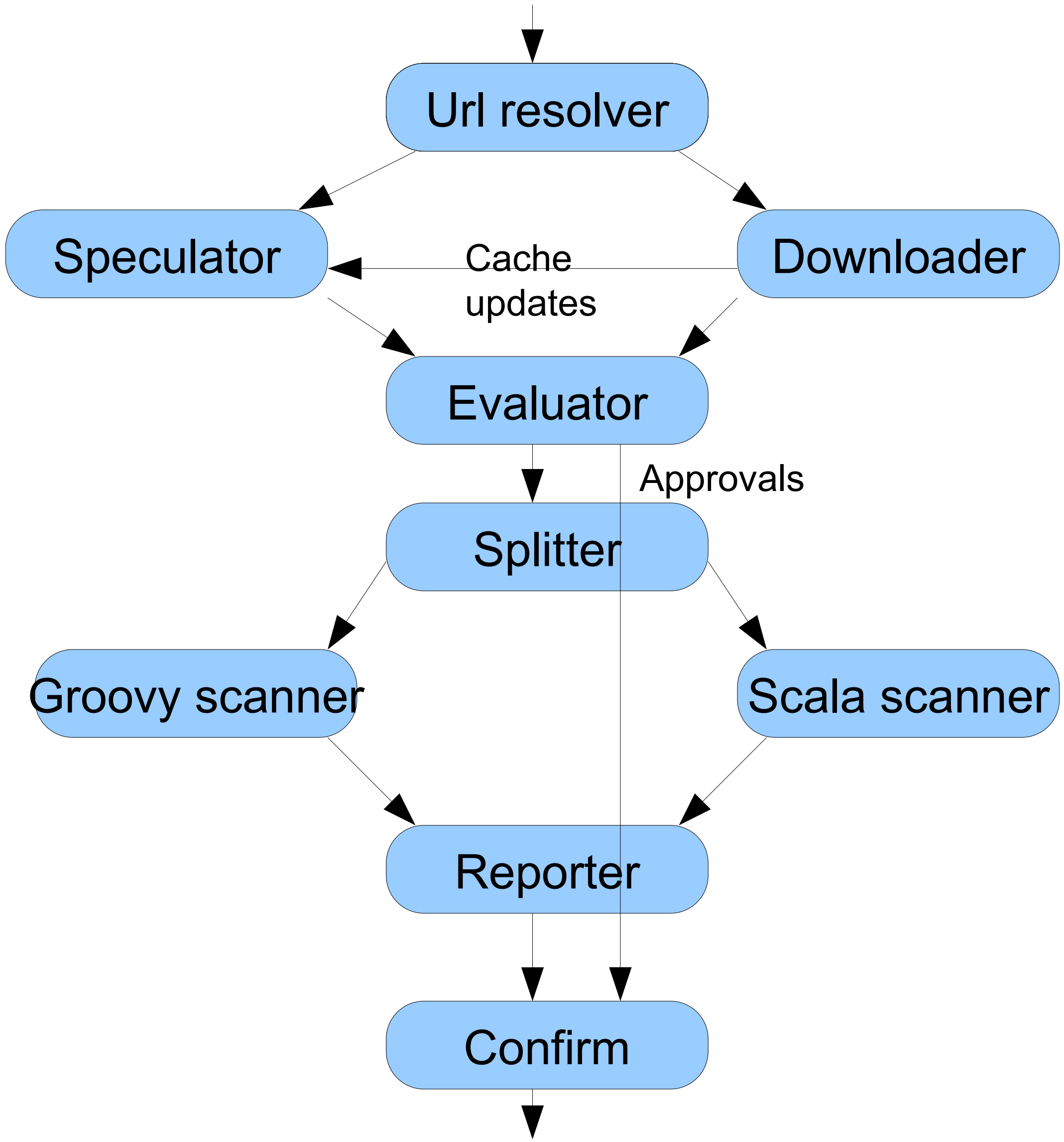
Pipeline DSL

```
def toProcess = new DataflowQueue()
def validated = new DataflowQueue()

toProcess |  {form -> process(form)} |
    {processedForm -> validate(processedForm)} | validated

submissions.each {toProcess << it}
```

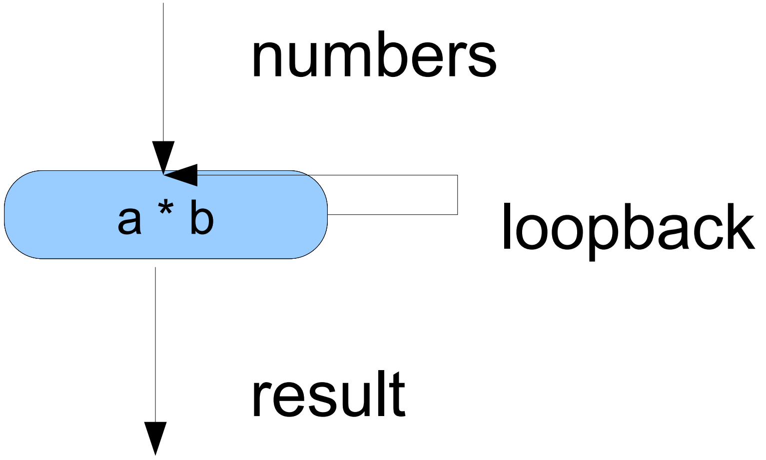

inProcess
process
validate
validated

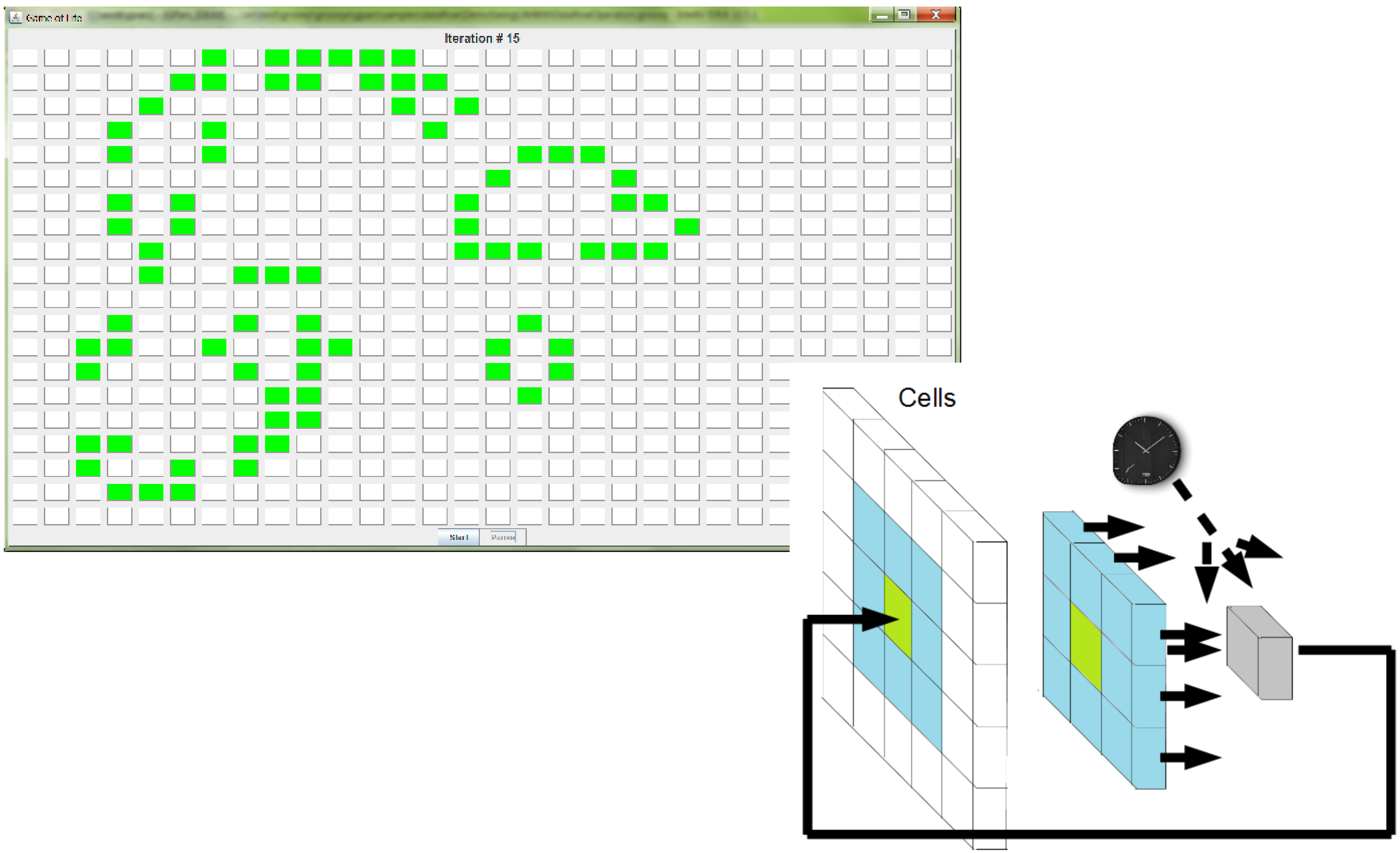

Url resolver
Speculator
Downloader
Cache
updates
Evaluator
Approvals
Splitter
Groovy scanner
Scala scanner
Reporter
Confirm

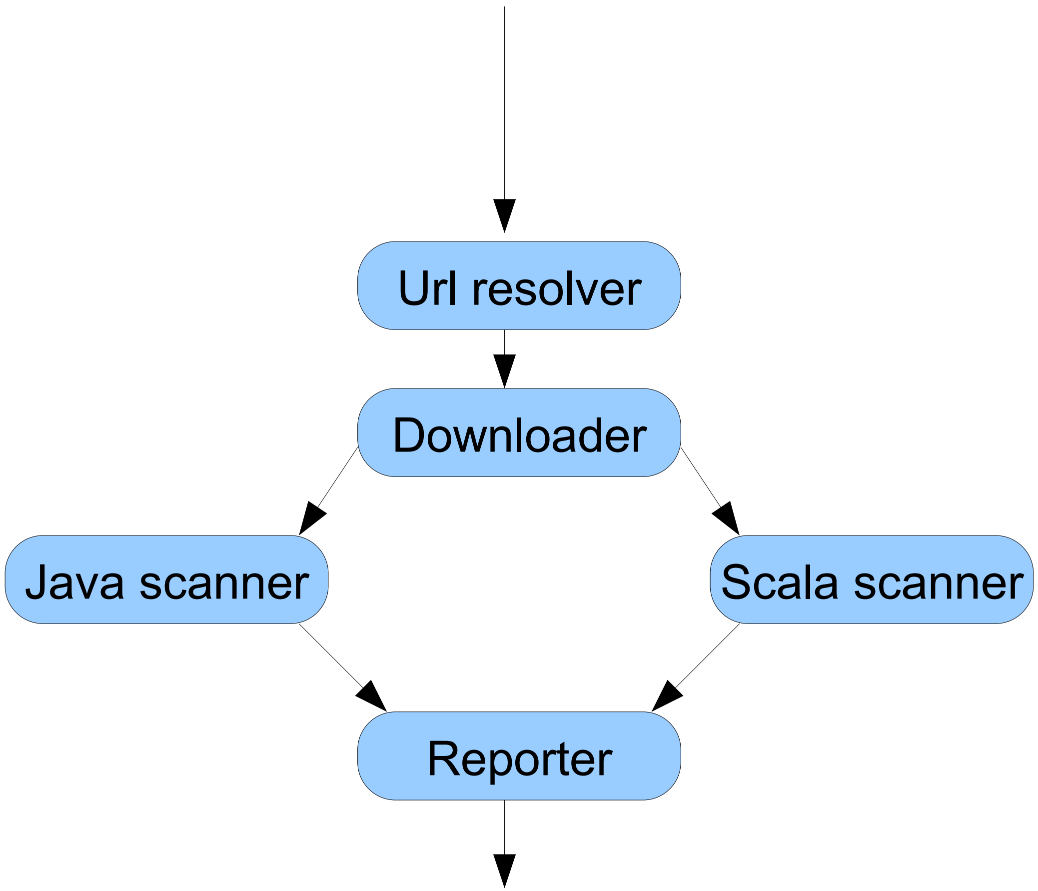
Dataflow Operators

```
operator(inputs: [headers, bodies, footers],
         outputs: [articles, summaries])
  {header, body, footer ->
    def article = buildArticle(header, body, footer)
    bindOutput(0, article)
    bindOutput(1, buildSummary(article))
  }
```

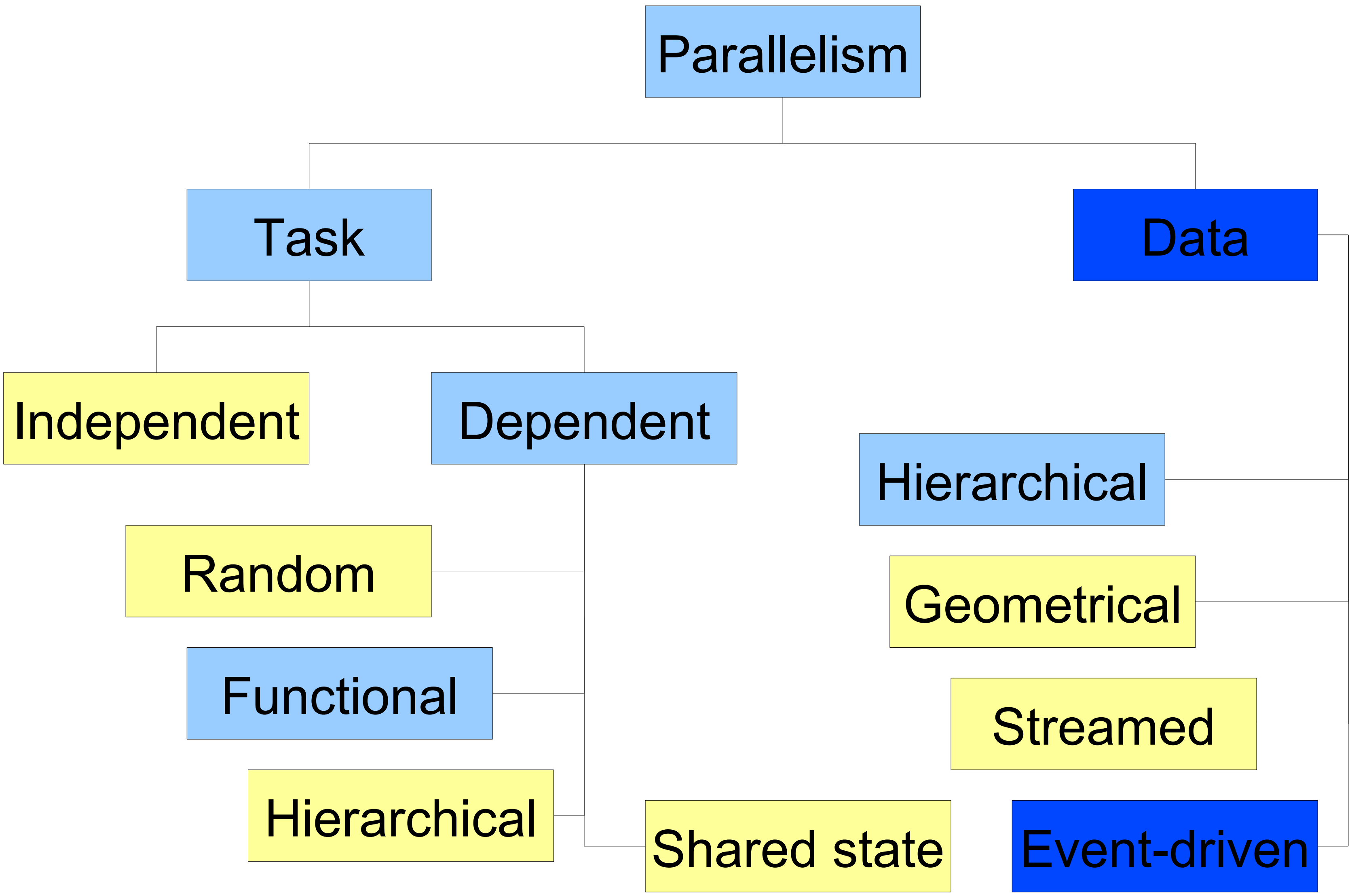
Factorial




Iteration # 15
Cells


Url resolver
Downloader
Java scanner
Scala scanner
Reporter

Actors



Parallelism
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Dependent
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Functional
Hierarchical
Shared state
Hierarchical
Geometrical
Streamed
Event-driven

Actors

Isolated state

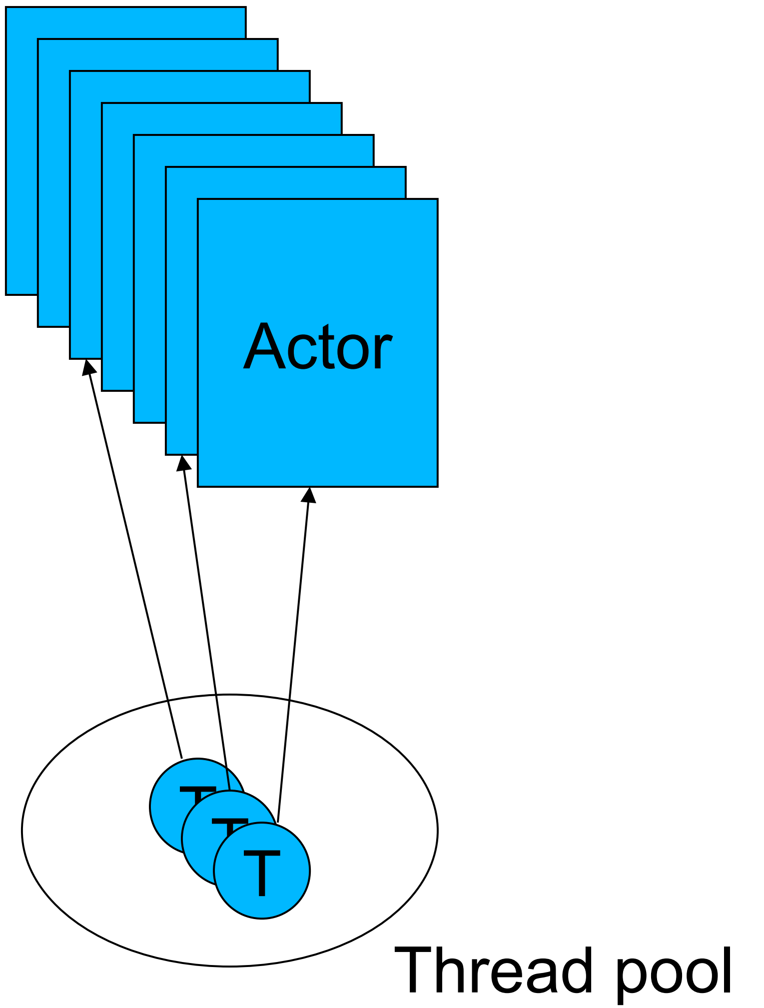
Active - shared threads

Async Communication

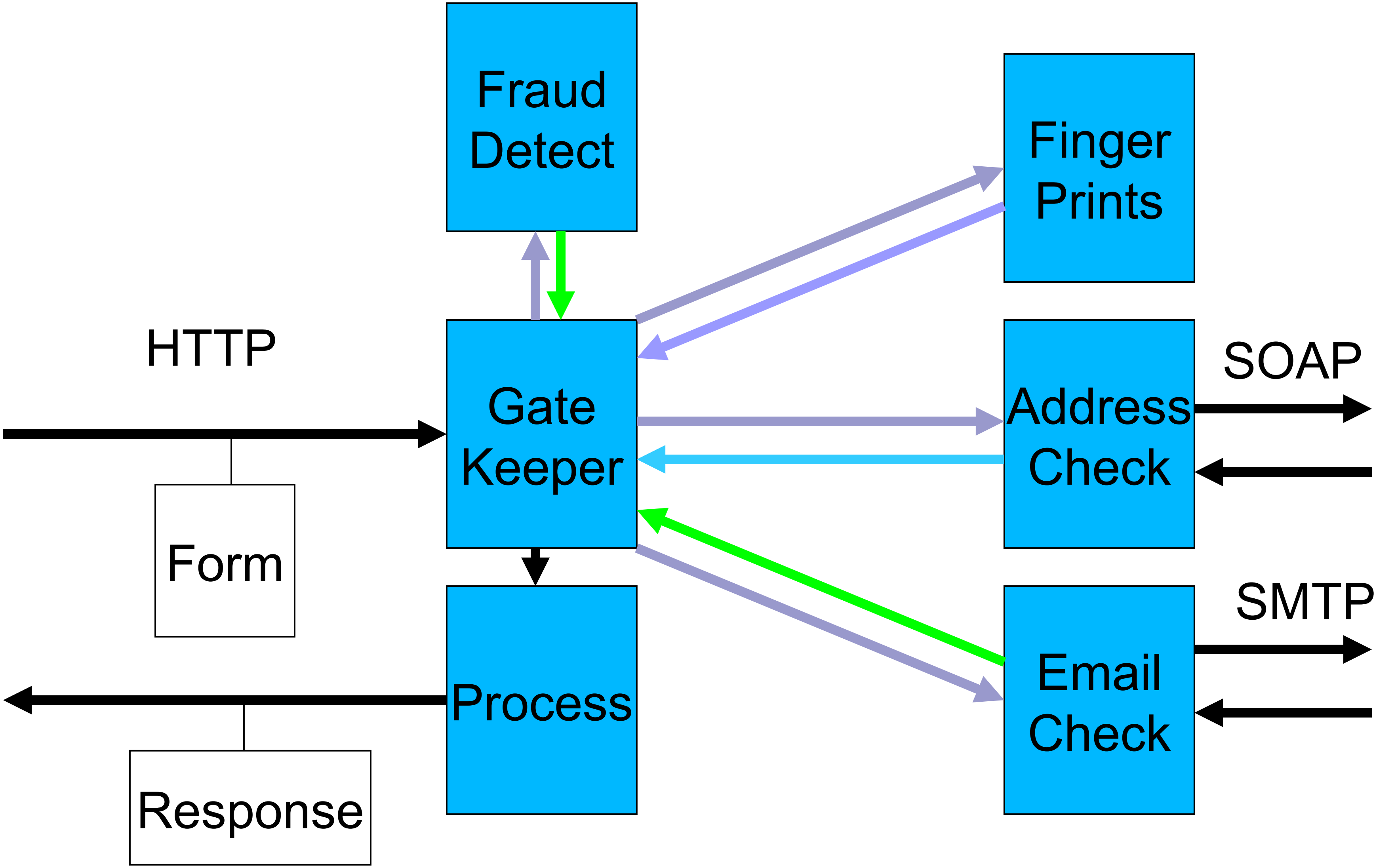
- Direct addressing
- Immutable messages

Activities:

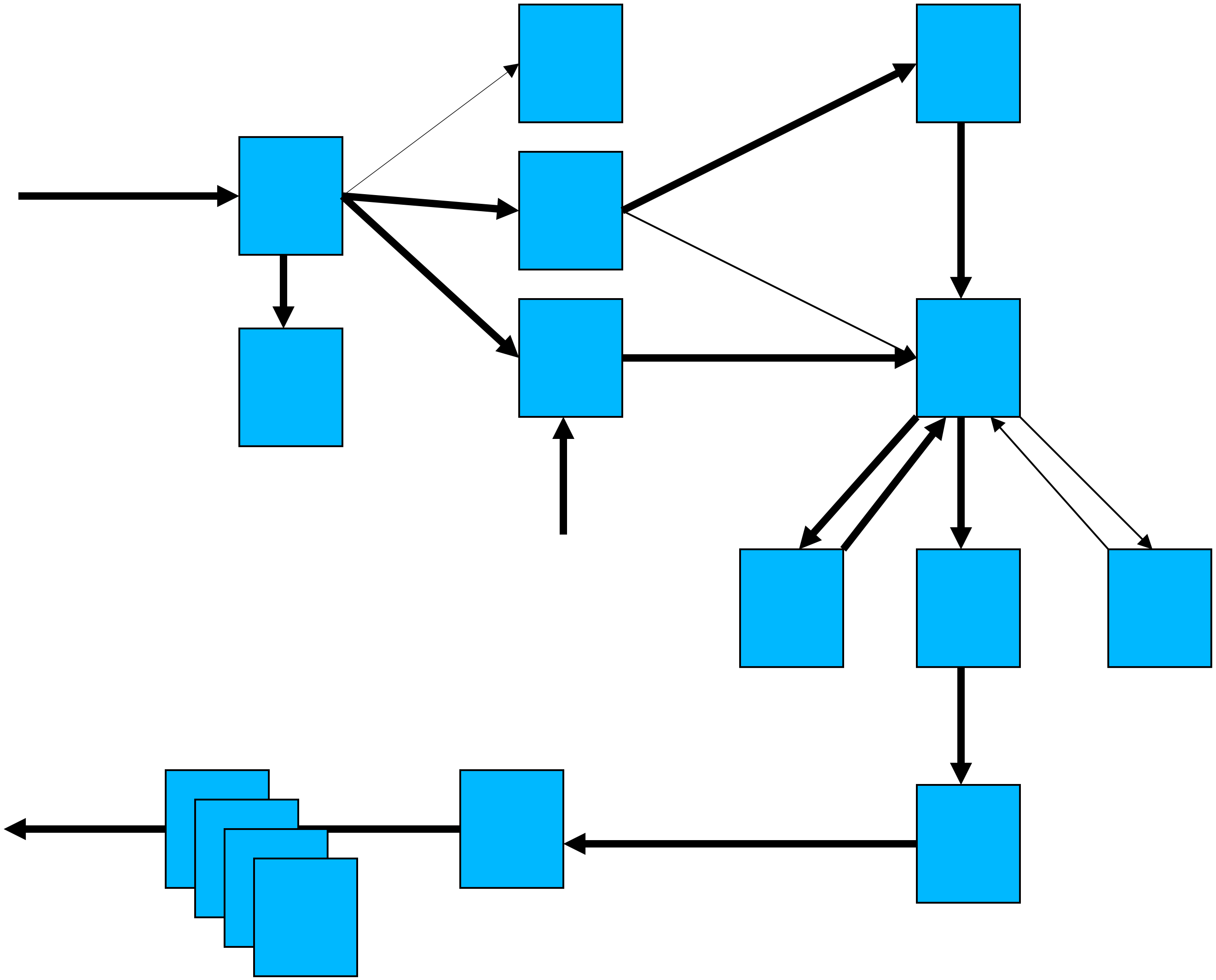
- Create a new actor
- Send a message
- Receive a message



Actors use


Fraud
Detect
Finger
Prints
HTTP
Gate
Keeper
SOAP
Address
Check
Form
SMTP
Email
Check
Process
Response

Actors patterns



Enricher

Router

Translator

Endpoint

Splitter

Agregator

Filter

Resequencer

Checker

Sending messages

```
buddy.send 10.eur

buddy << new Book(title:'Groovy Recipes',
                  author:'Scott Davis')

def canChat = buddy.sendAndWait 'Got time?'

buddy.sendAndContinue 'Need money!', {cash->
    pocket.add cash
}
```

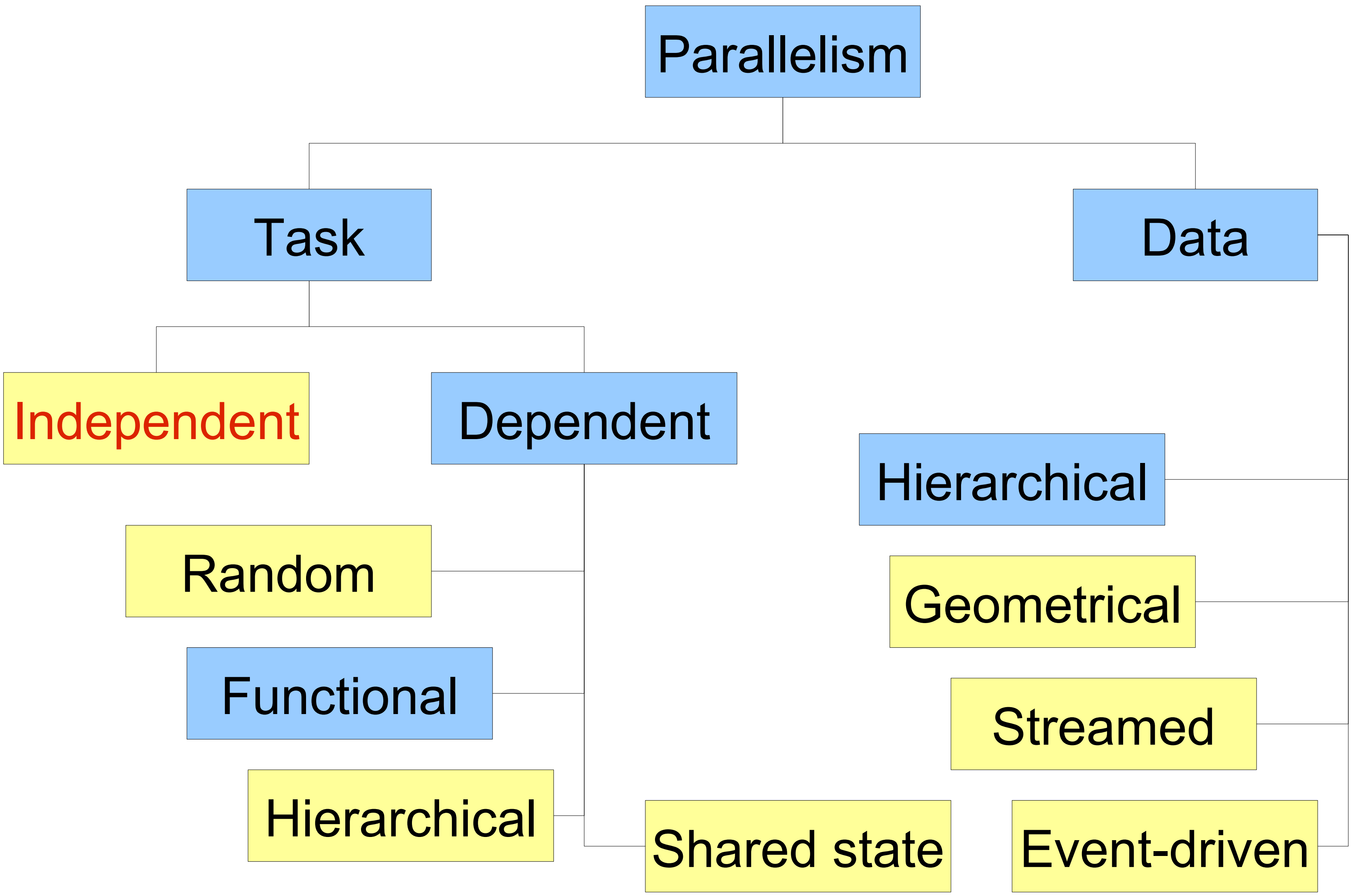
Event driven – actors

```
class MyActor extends DynamicDispatchActor {
   private int counter = 0

   public void onMessage(String msg) {
      this.counter += msg.size()
   }
   public void onMessage(Integer number) {
      this.counter += number
   }
   public void onMessage(Money cash) {
      this.counter += cash.amount
      reply 'Thank you'
   }
}
```

Event driven – active objects

```
@ActiveObject
class MyCounter {
    private int counter = 0


    @ActiveMethod
    def incrementBy(int value) {
        println "Received an integer: $value"
        this.counter += value
    }
}
```

Conclusion


Parallelism
Task
Data
Independent
Dependent
Random
Functional
Hierarchical
Shared state
Hierarchical
Geometrical
Streamed
Event-driven

Summary

Parallelism is not hard, multi-threading is

Jon Kerridge, Napier University

References

http://groovy-lang.org

http://grails.org

http://groovyconsole.appspot.com/

http://www.manning.com/koenig2/