

High-level concurrency concepts



Václav Pech

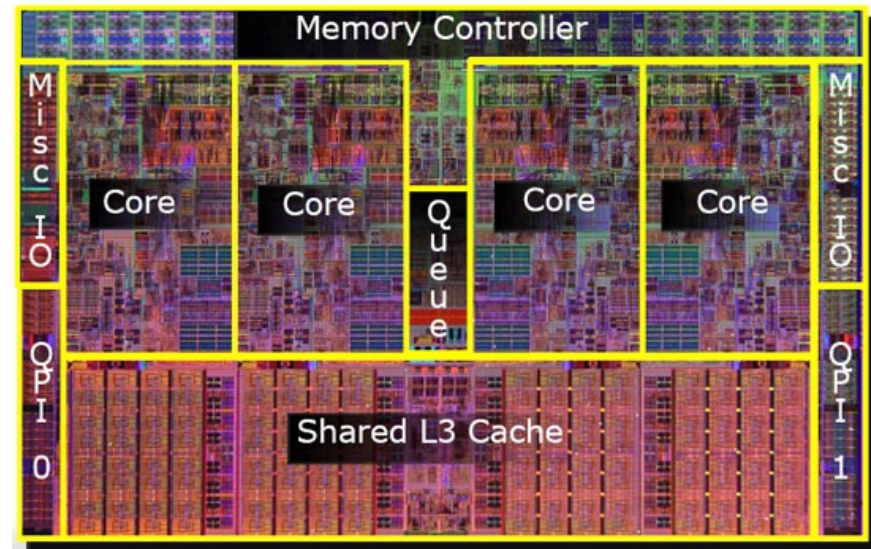
NPRG014 2016/2017

<http://jroller.com/vaclav>

<http://www.vaclavpech.eu>

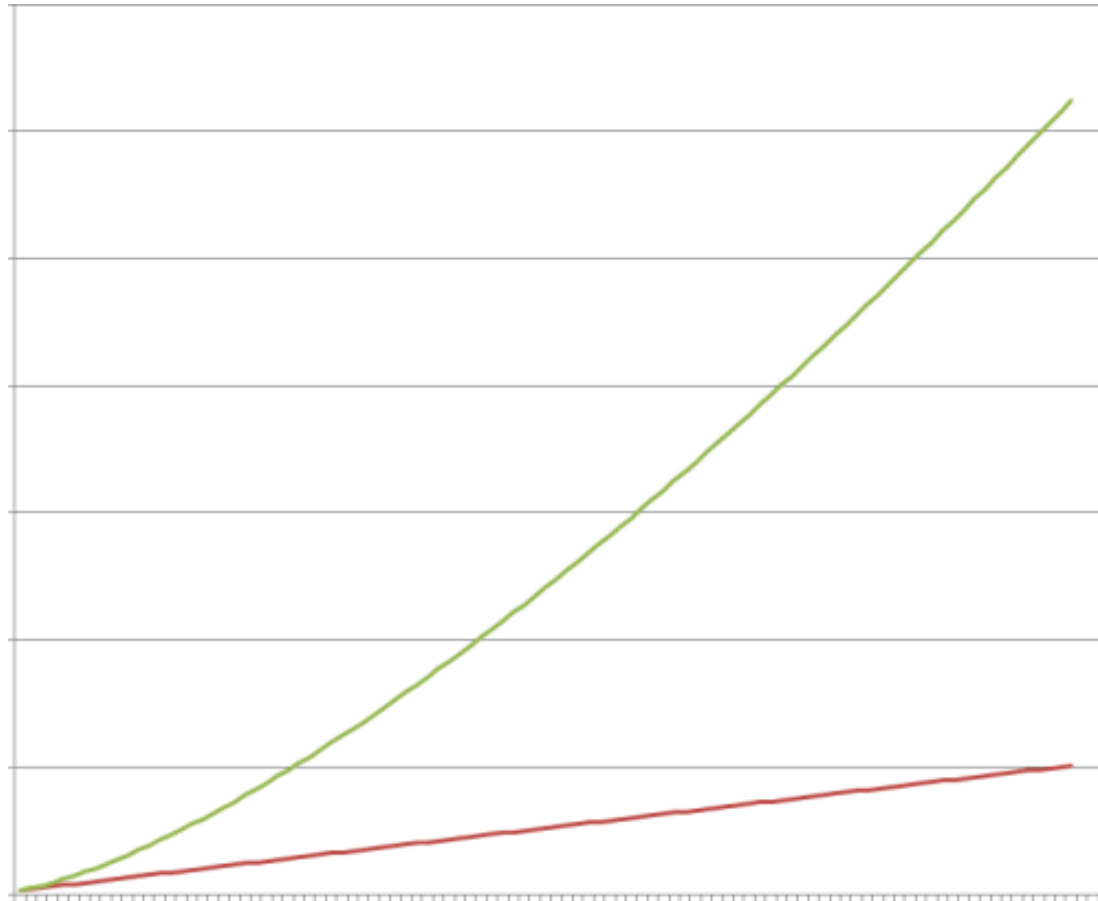
@vaclav_pech

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!

```
public class Counter {  
    private volatile static long count = 0;  
  
    public Counter() {  
  
        count = count + 1;  
  
    }  
}
```


Dealing with threads sucks!

```
public class Counter {  
    private static long count = 0;  
  
    public Counter() {  
        synchronized (this) {  
            count++;  
        }  
    }  
}
```

Dealing with threads sucks!

```
public class Counter {  
    private static long count = 0;  
  
    public Counter() {  
        synchronized (this.getClass()) {  
            count++;  
        }  
    }  
}
```

Dealing with threads sucks!

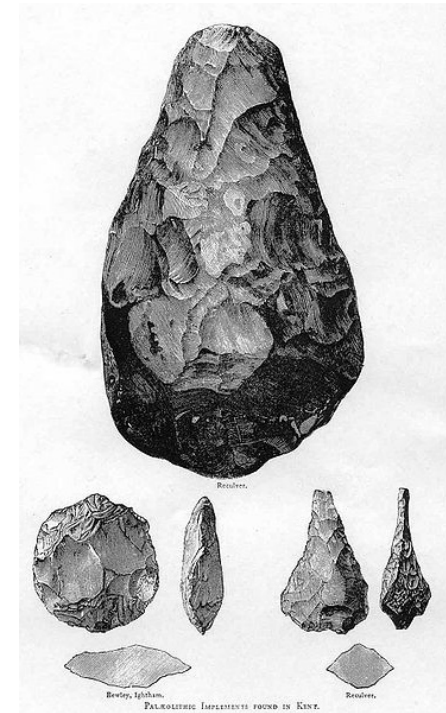
```
public class Counter {  
    private Long count = 0;  
  
    public doSomething() {  
        synchronized (count) {  
            count++;  
        }  
    }  
}
```

Dealing with threads sucks!

```
public class Counter {  
    private Long count = 0;  
  
    public doSomething() {  
        synchronized (count) {  
            count = new Long(count.longValue() + 1);  
        }  
    }  
}
```

Dealing with threads sucks!

```
public class ClickCounter implements ActionListener {  
    public ClickCounter(JButton button) {  
        button.addActionListener(this);  
    }  
  
    public void actionPerformed(final ActionEvent e) {  
        ...  
    }  
}
```

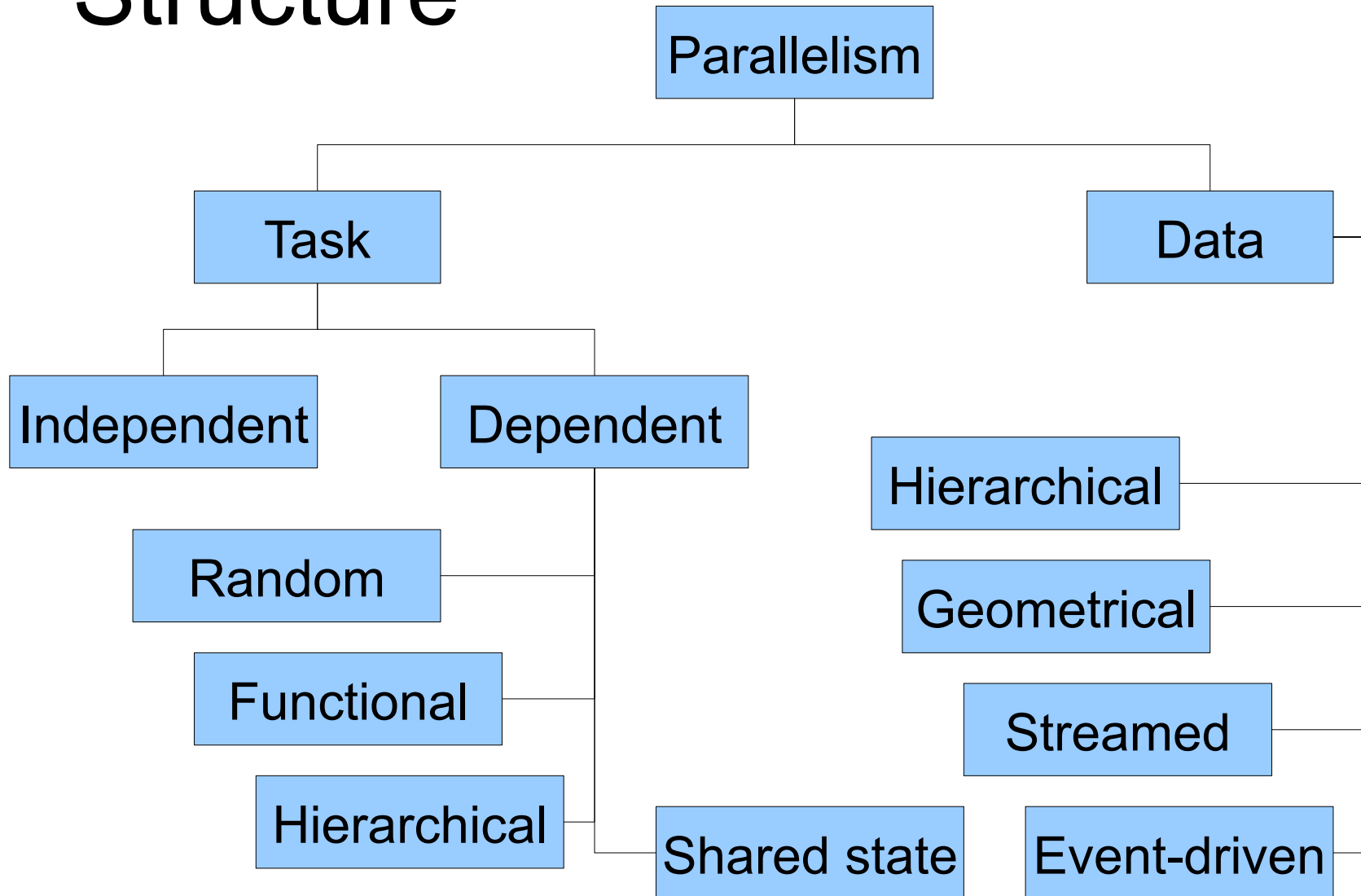


Why high-level concurrency?

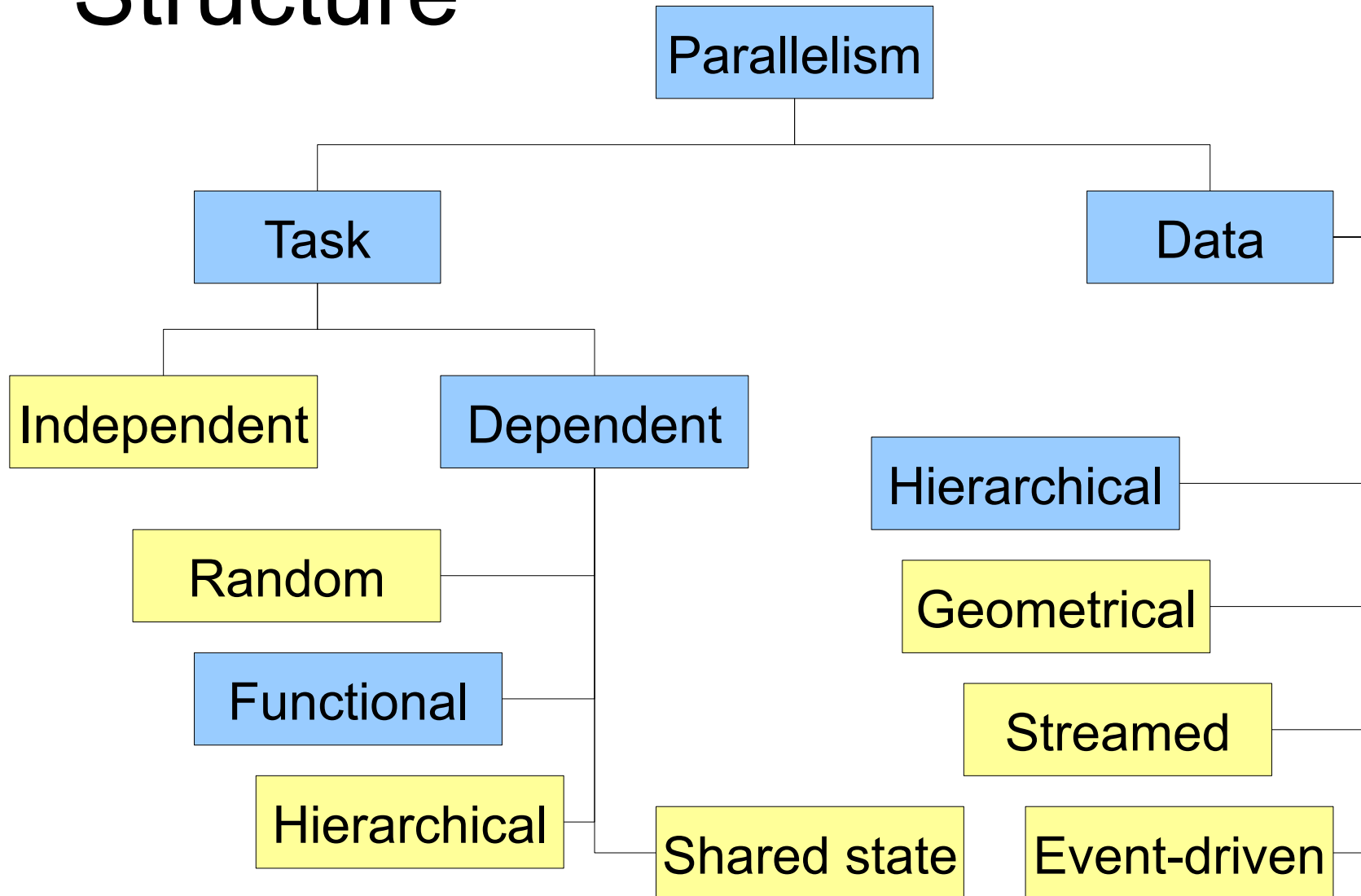
Multithreaded programs today work mostly by accident!



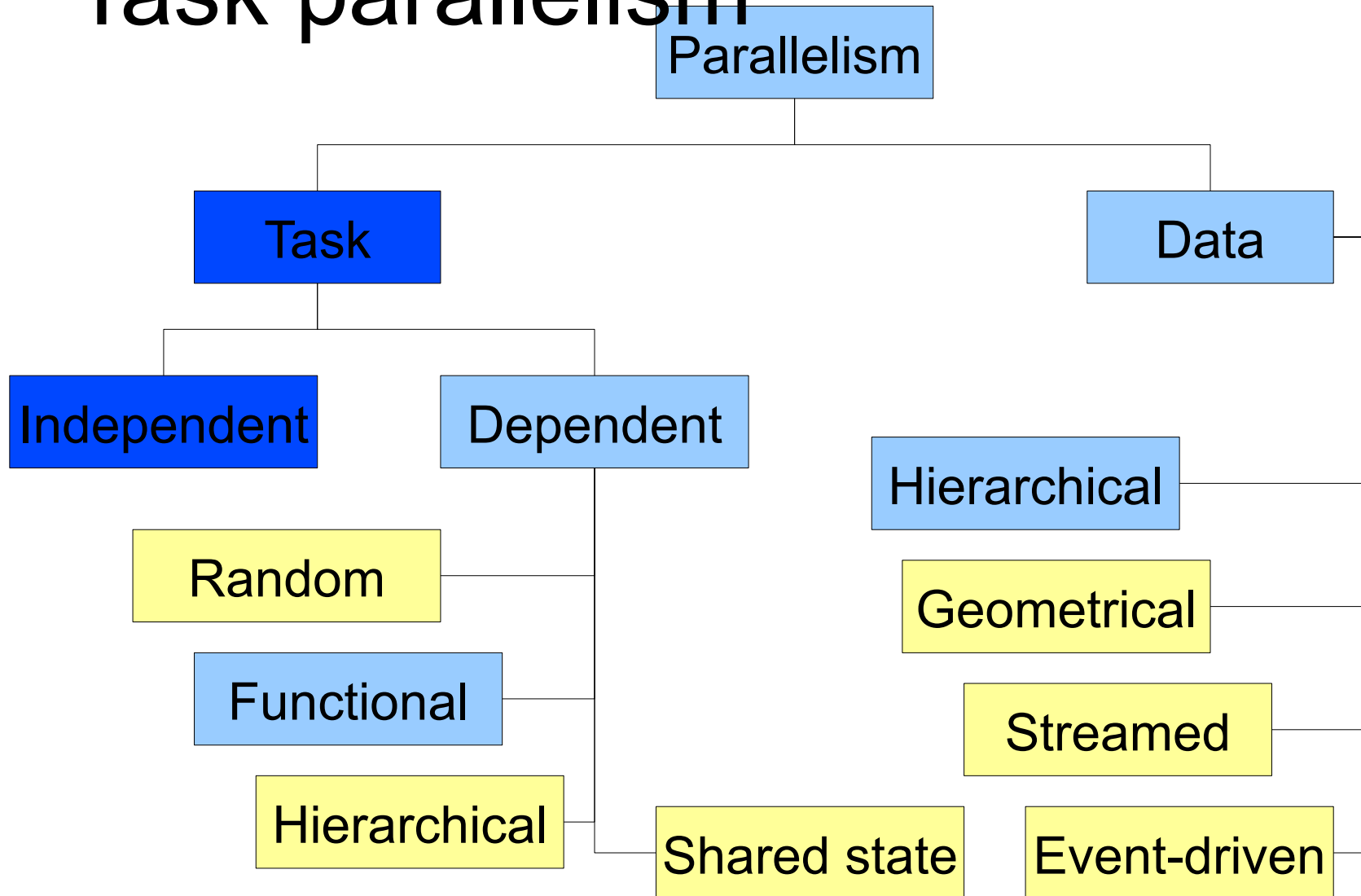
Structure



Structure



Task parallelism





Asynchronous invocation

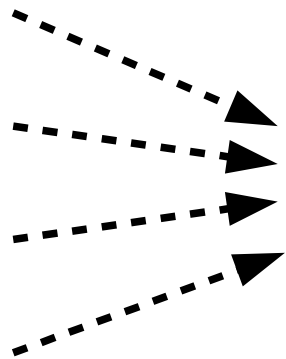
```
Future f = threadPool.submit(calculation);
```

```
...
```

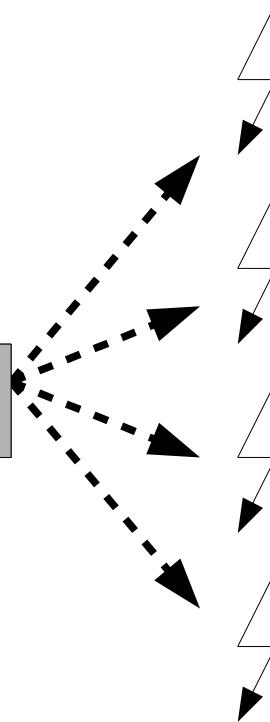
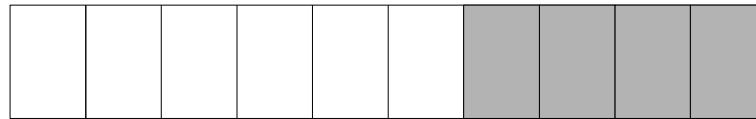
```
System.out.println(Result:  + f.get());
```

Thread Pool

Tasks

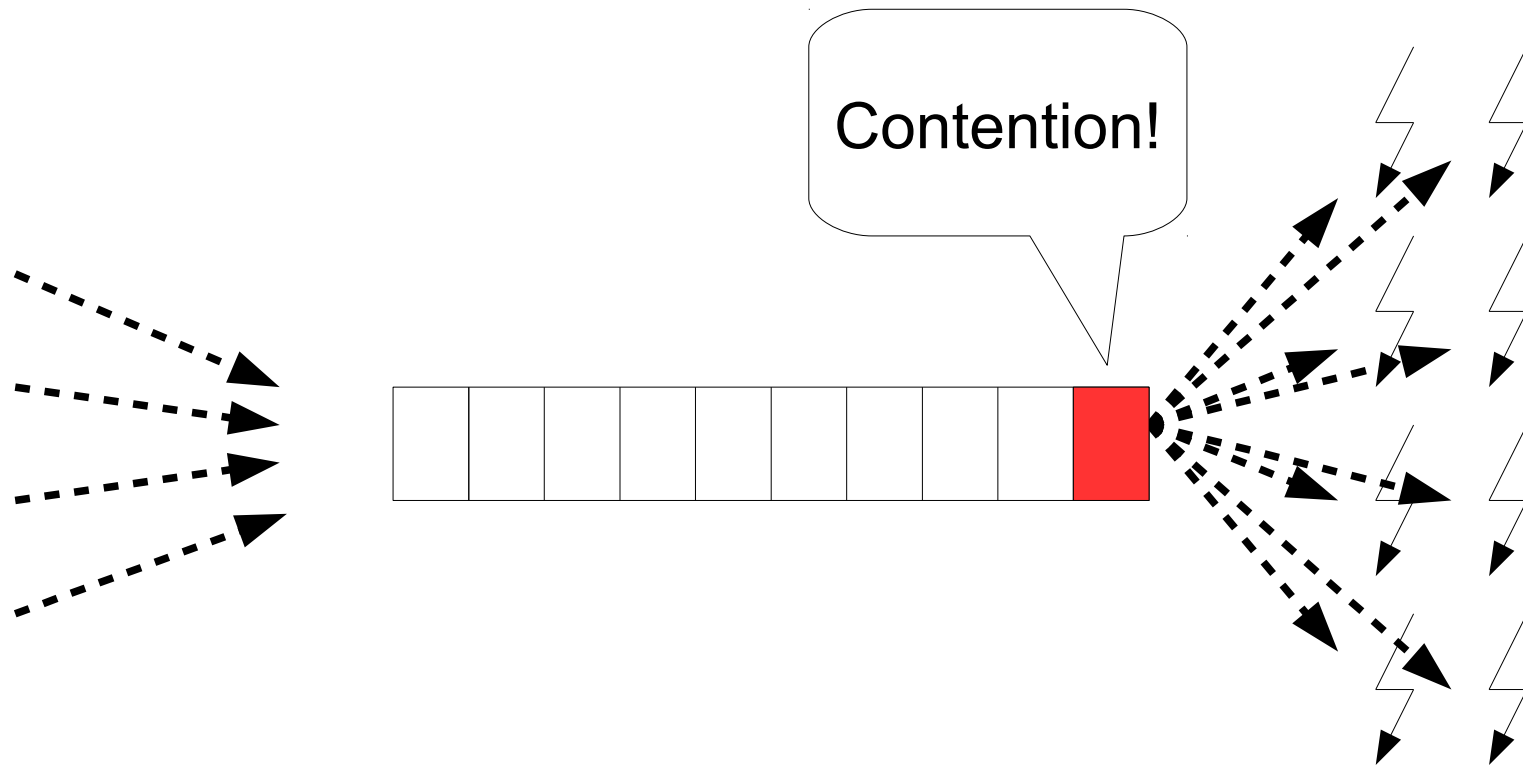


Queue

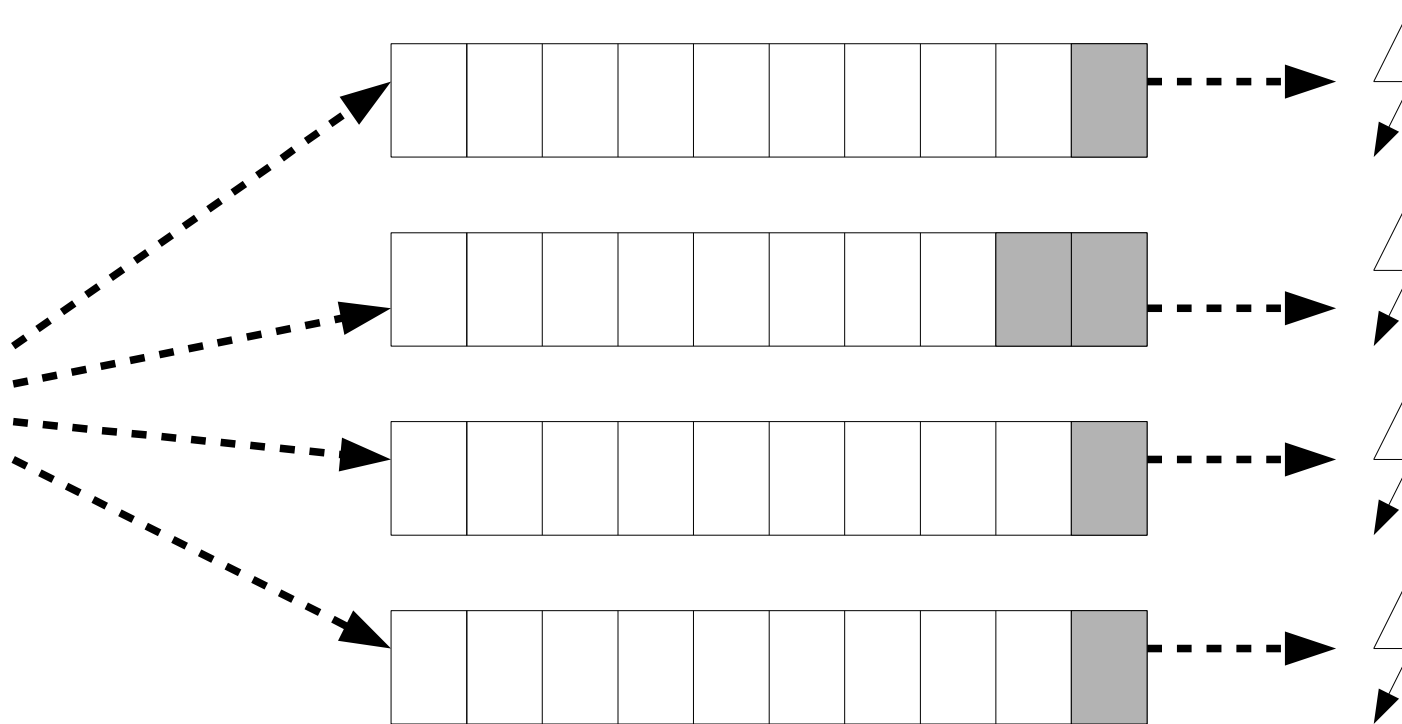


Worker threads

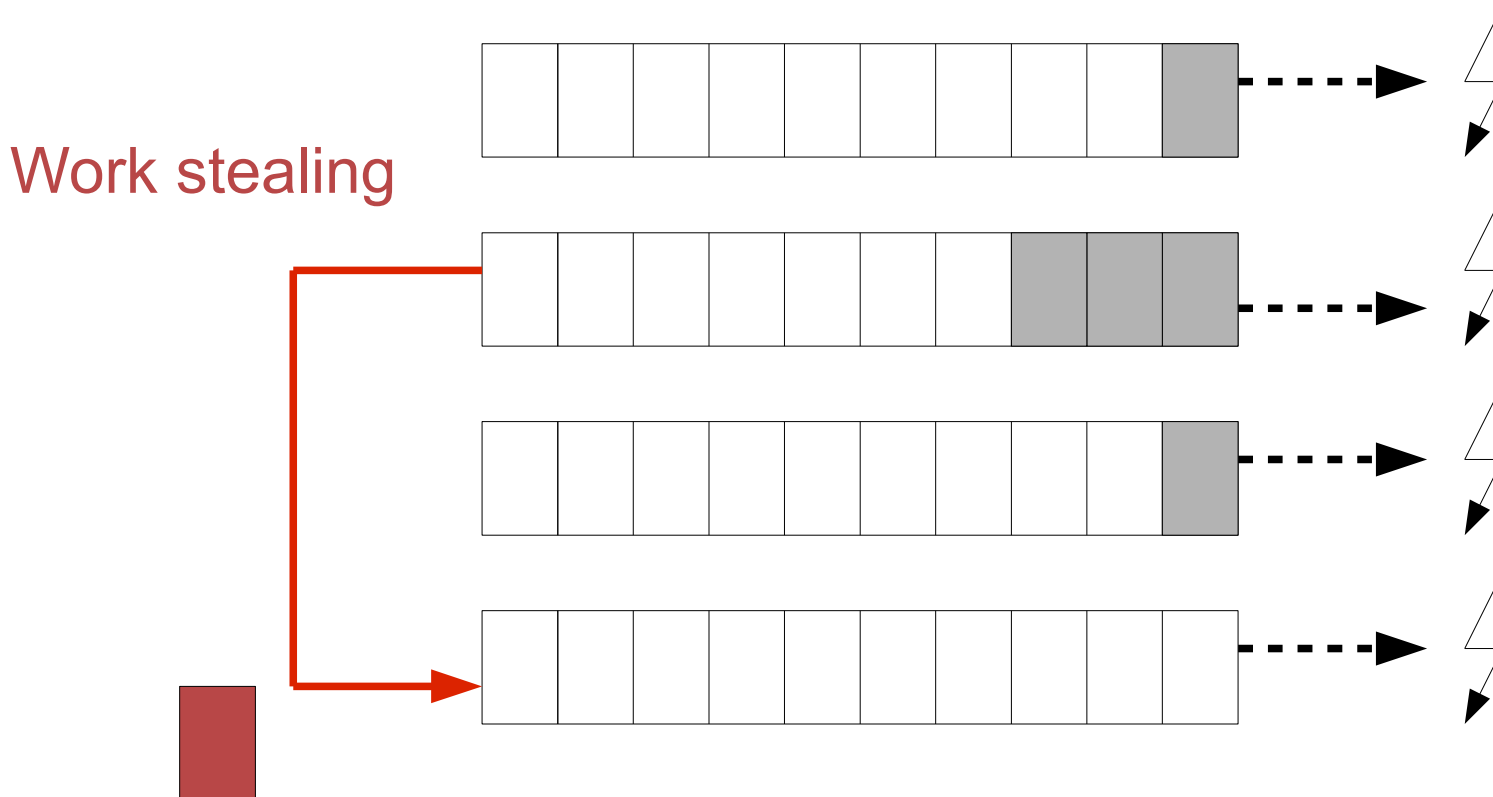
Thread Pool



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 {
```

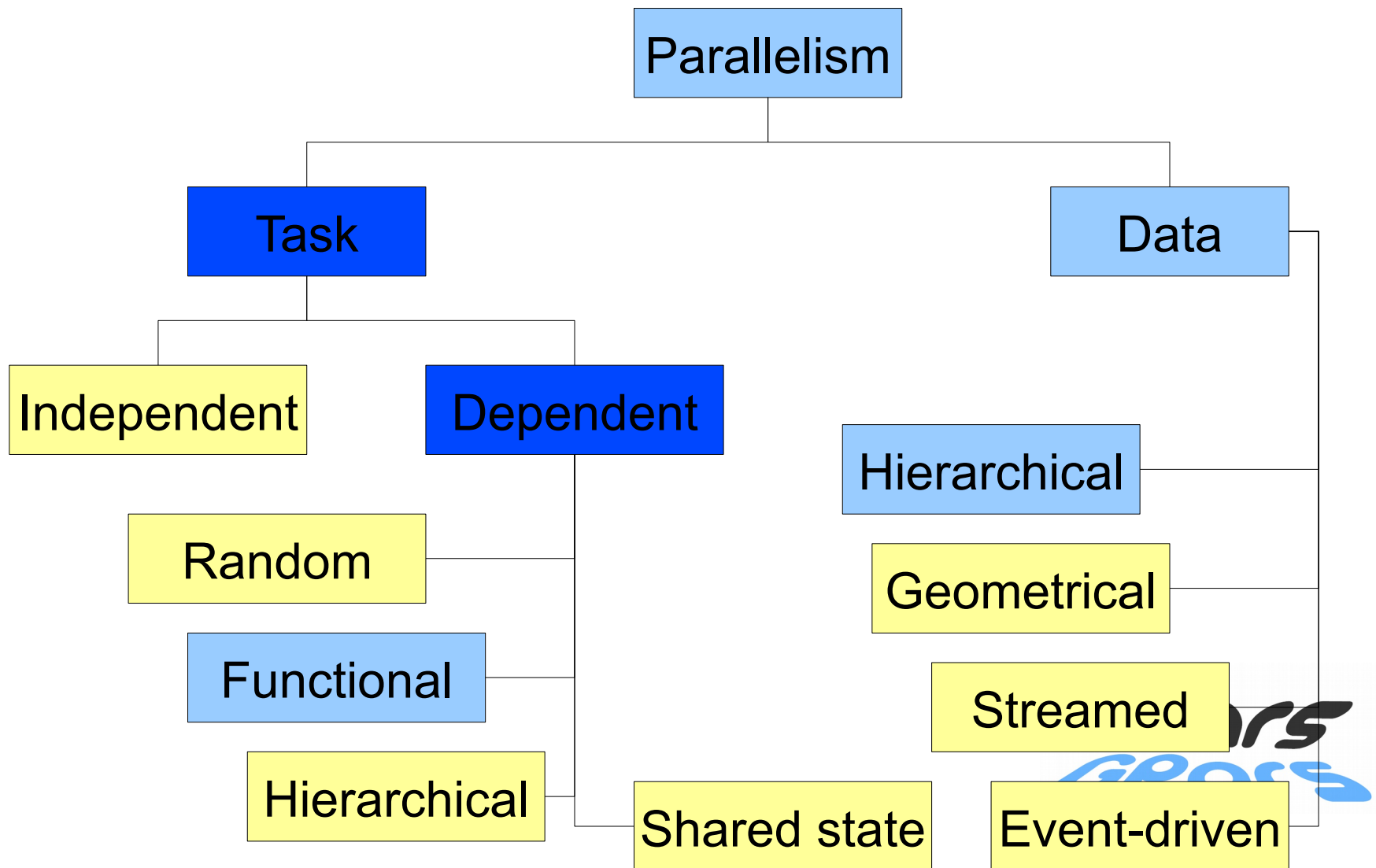
```
        form.process()
```

```
    }
```

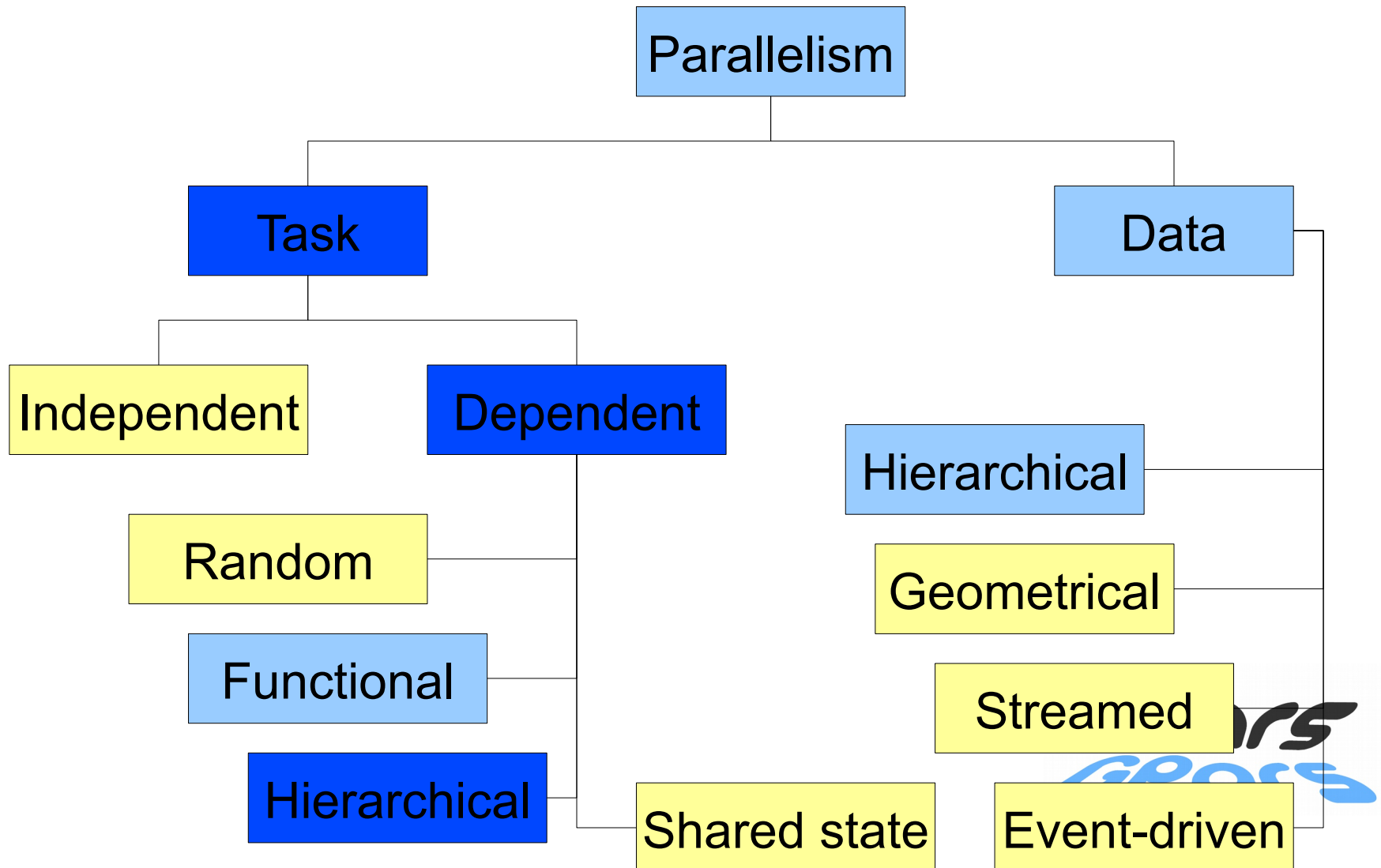
```
}
```



Dependent tasks



Dependent tasks

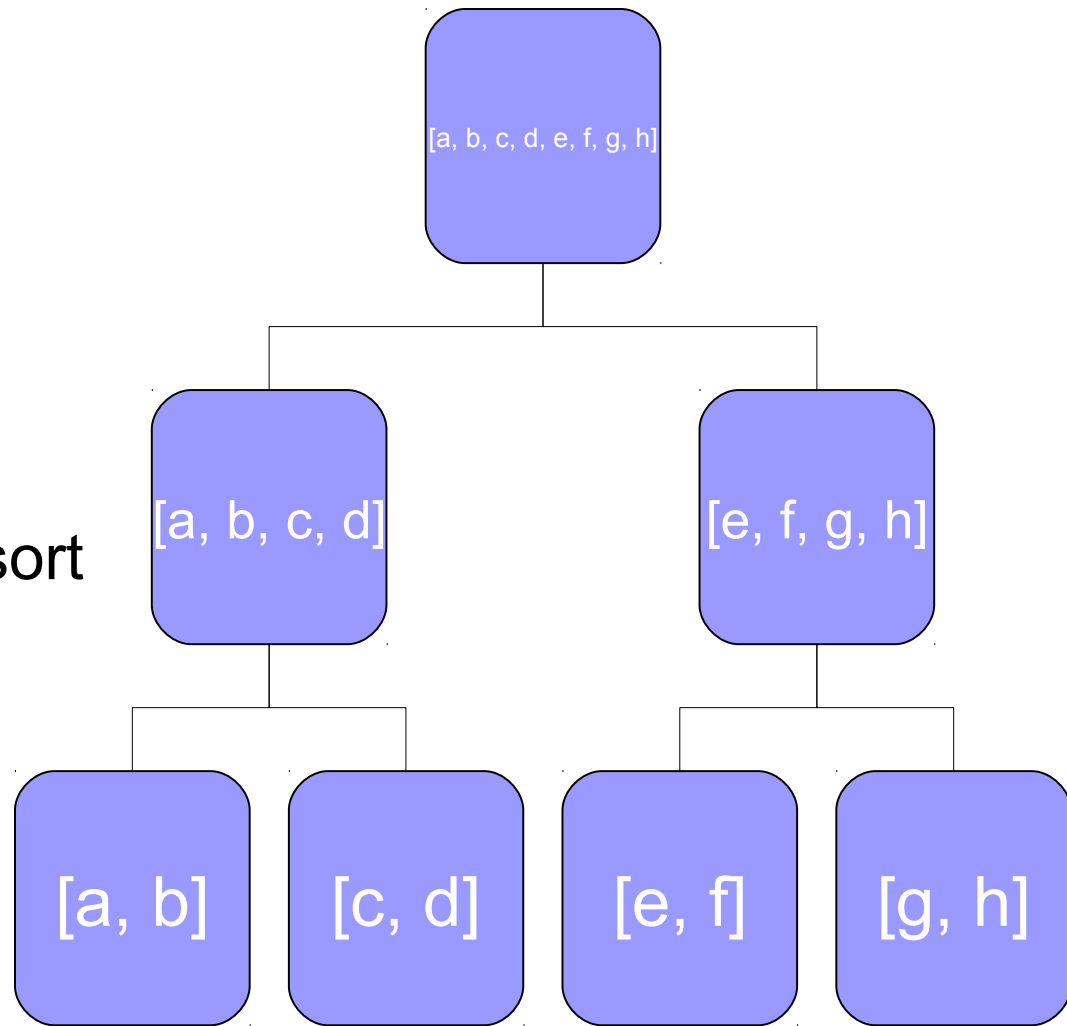


Hierarchical decomposition

[64, 63, 62, 61, 60, 59, 58, 57, 56, 55, 54, 53, 52, 51, 50, 49, 48, 47, 46, 45, 44, 43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29, 28, 27, 26, 25, 24, 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1]														
[64, 63, 62, 61, 60, 59, 58, 57, 56, 55, 54, 53, 52, 51, 50, 49, 48, 47, 46, 45, 44, 43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33]											[32, 31, 30, 29, 28, 27, 26, 25, 24, 23, 22, 21, 20, 19, 18,			
[64, 63, 62, 61, 60, 59, 58, 57, 56, 55, 54, 53, 52, 51, 50, 49]							[48, 47, 46, 45, 44, 43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33]					[32, 31, 30, 29, 28, 27, 26, 25, 24, 23, 22, 21, 20, 19, 18,		
[64, 63, 62, 61, 60, 59, 58, 57]			[56, 55, 54, 53, 52, 51, 50, 49]				[48, 47, 46, 45, 44, 43, 42, 41]			[40, 39, 38, 37, 36, 35, 34, 33]				
			[56, 55, 54, 53]		[49, 50, 51, 52]					[40, 39, 38, 37]			[33, 34, 35, 36]	
[56, 55]				[51, 52]		[49, 50]					[40, 39]		[35, 36]	[33, 34]

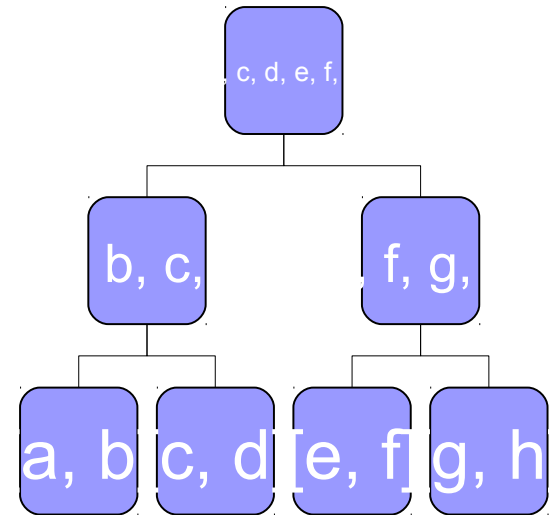
Fork/Join

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

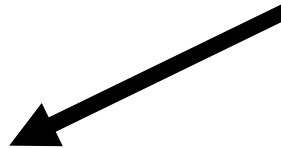


Fork/Join (GPar)

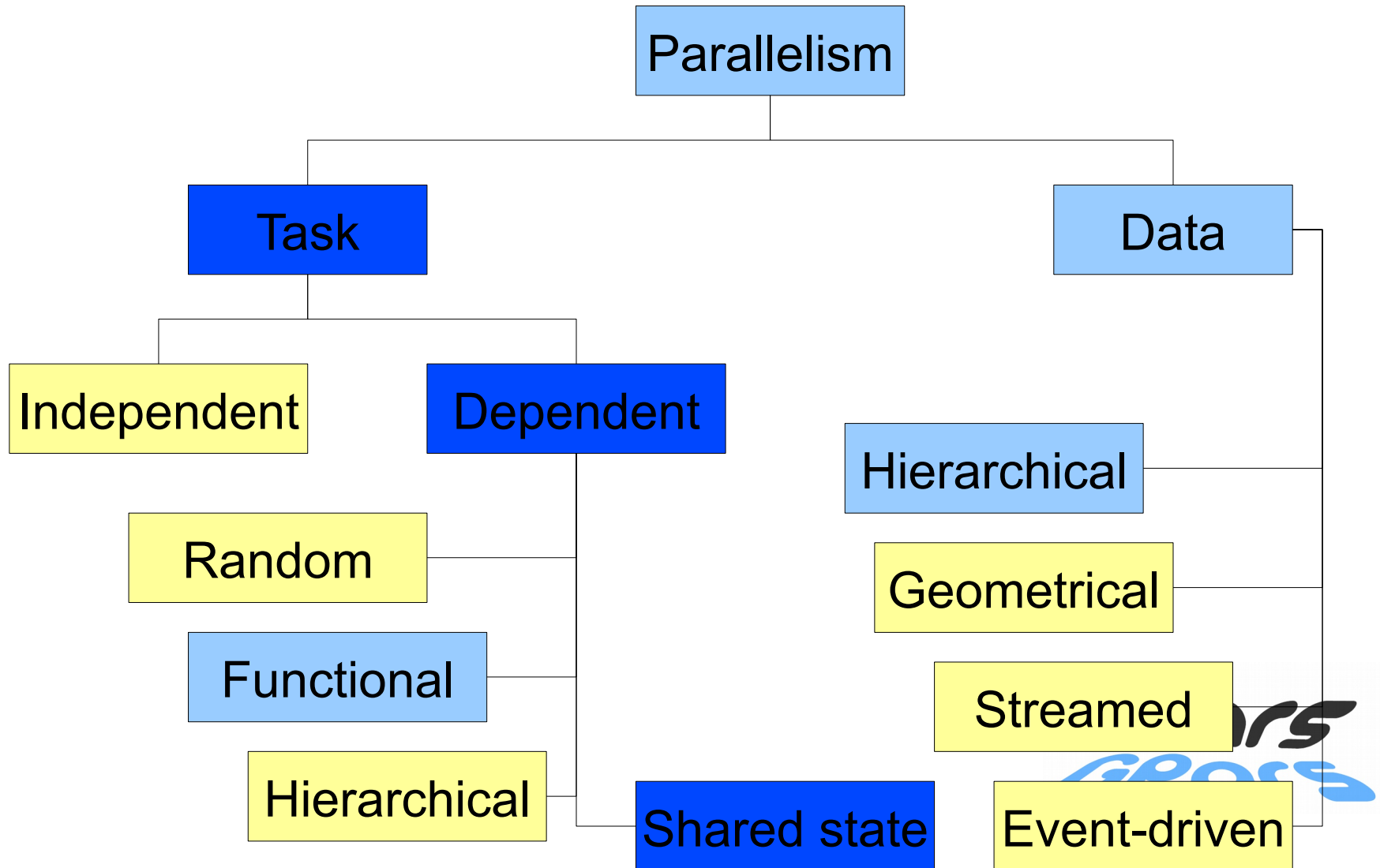
```
{currentDir ->
  long count = 0;
  currentDir.eachFile {
    if (it.isDirectory()) {
      forkOffChild it
    } else {
      count++
    }
  }
  return count + childrenResults.sum(0)
}
```



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

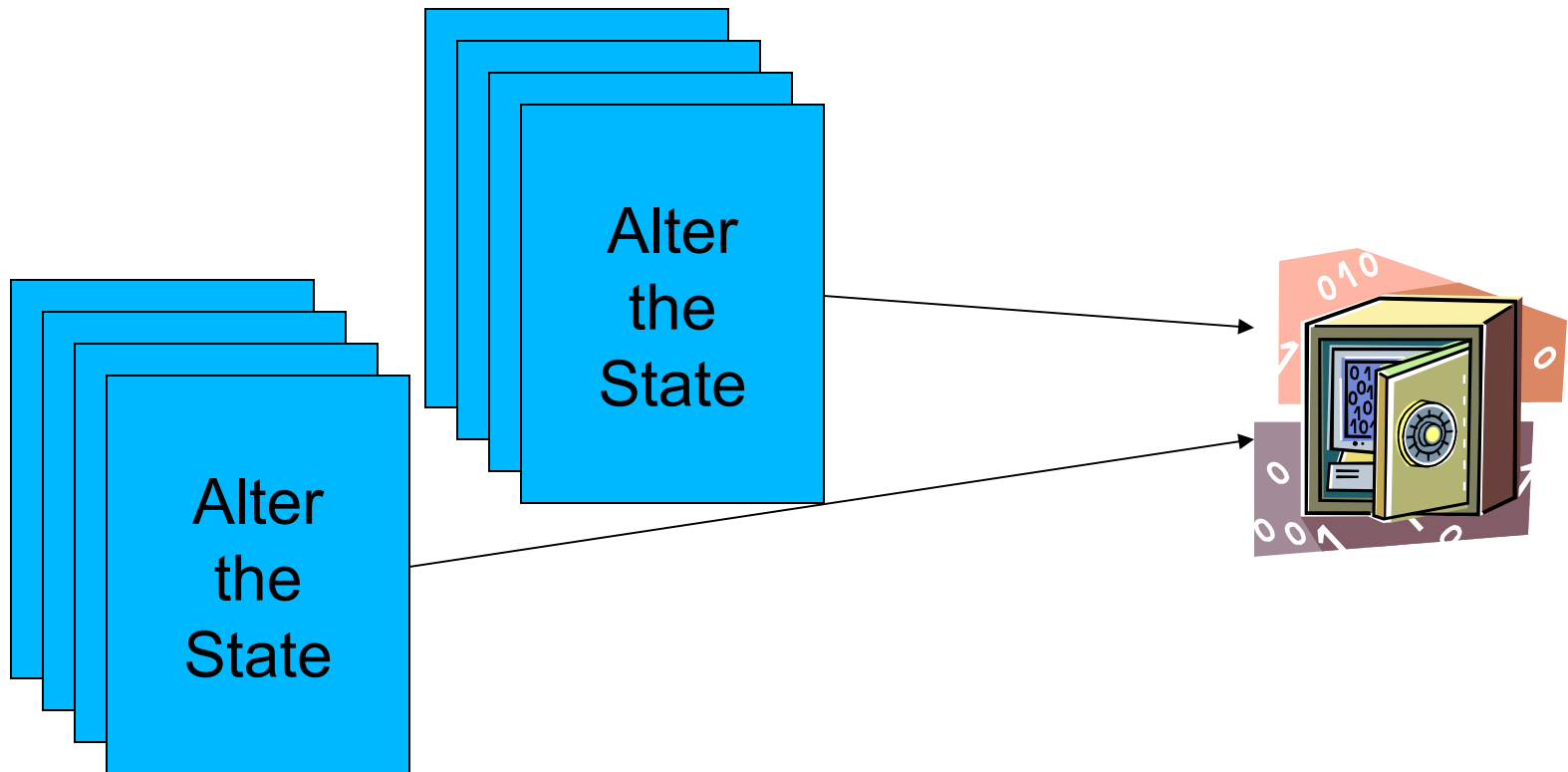
Frequently misused

When really needed, use

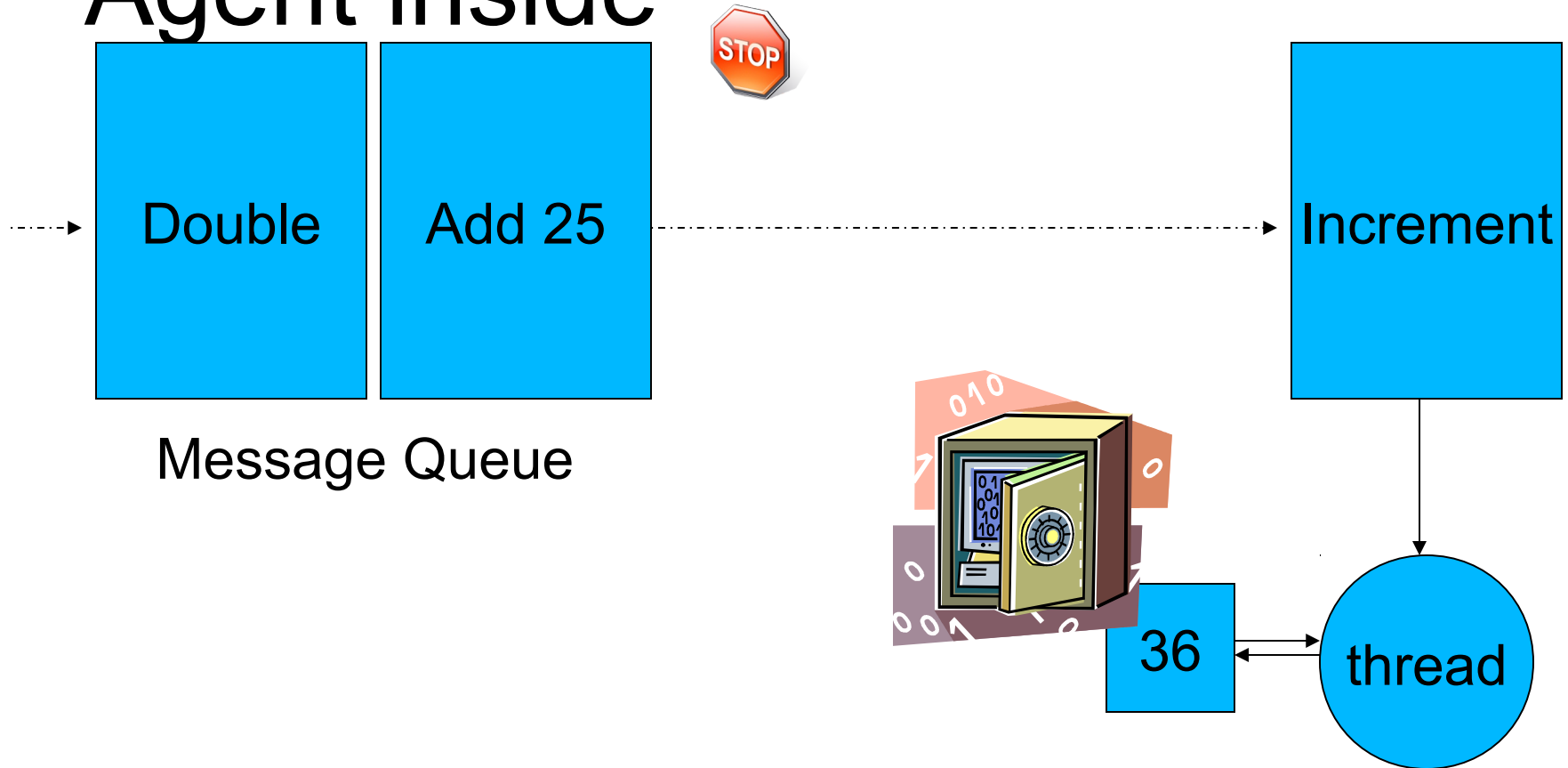
- Agents
- Software Transactional Memory
- Locks

Agent

- Lock **Shared Mutable State** in a **Safe**



Agent inside



Sharing through agents

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



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  
}
```


Persistent Data Structures

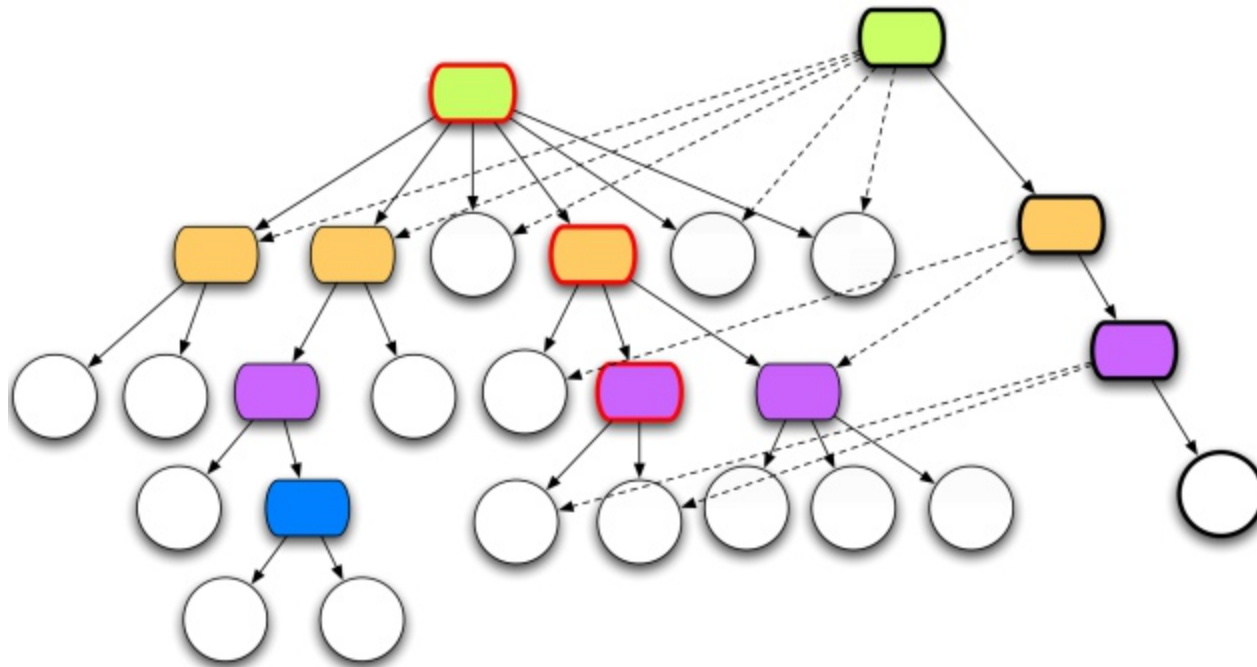
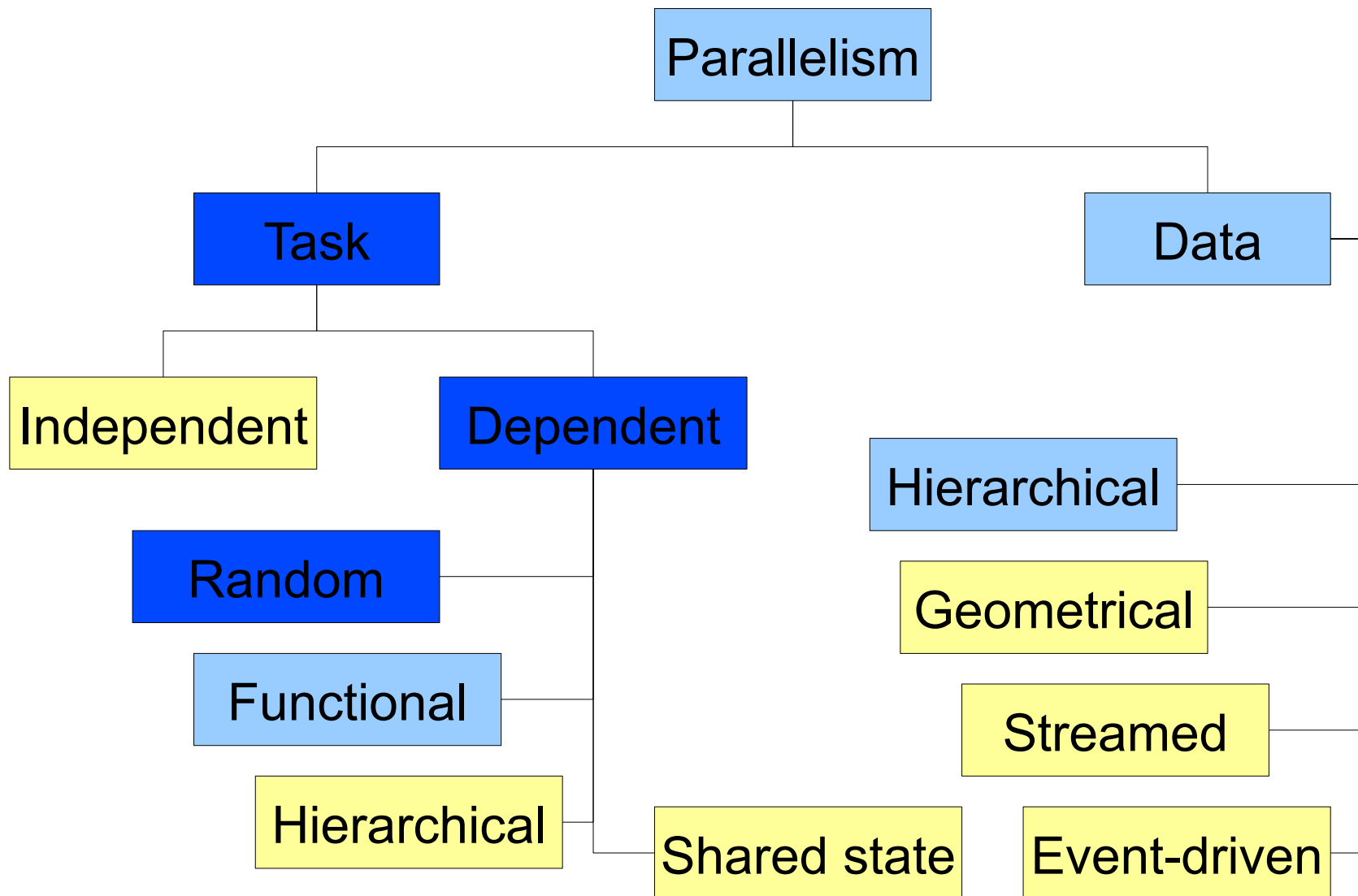


Illustration taken from Rich Hickey's presentation. Copyright Rich Hickey 2009

Random task dependency

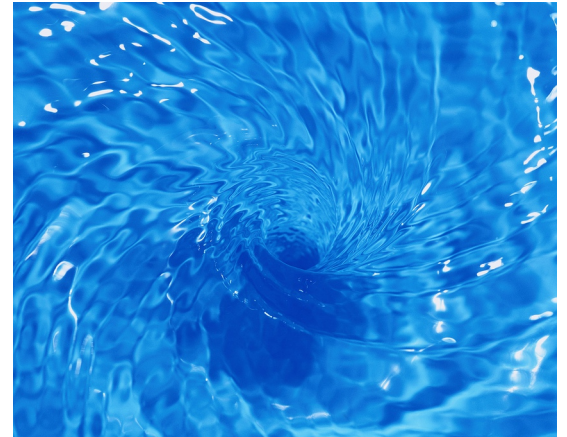


Dataflow Concurrency

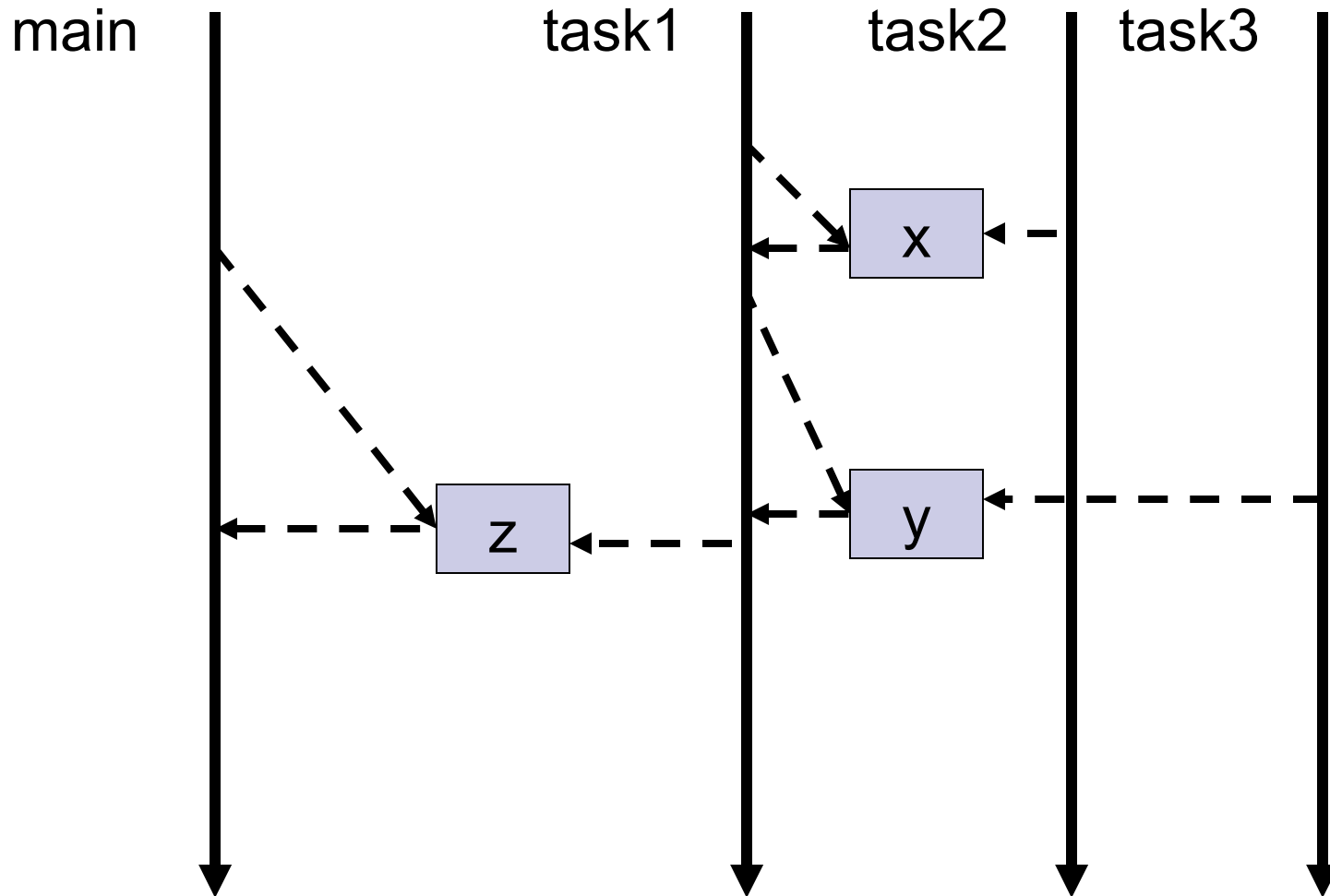
No race-conditions

No live-locks

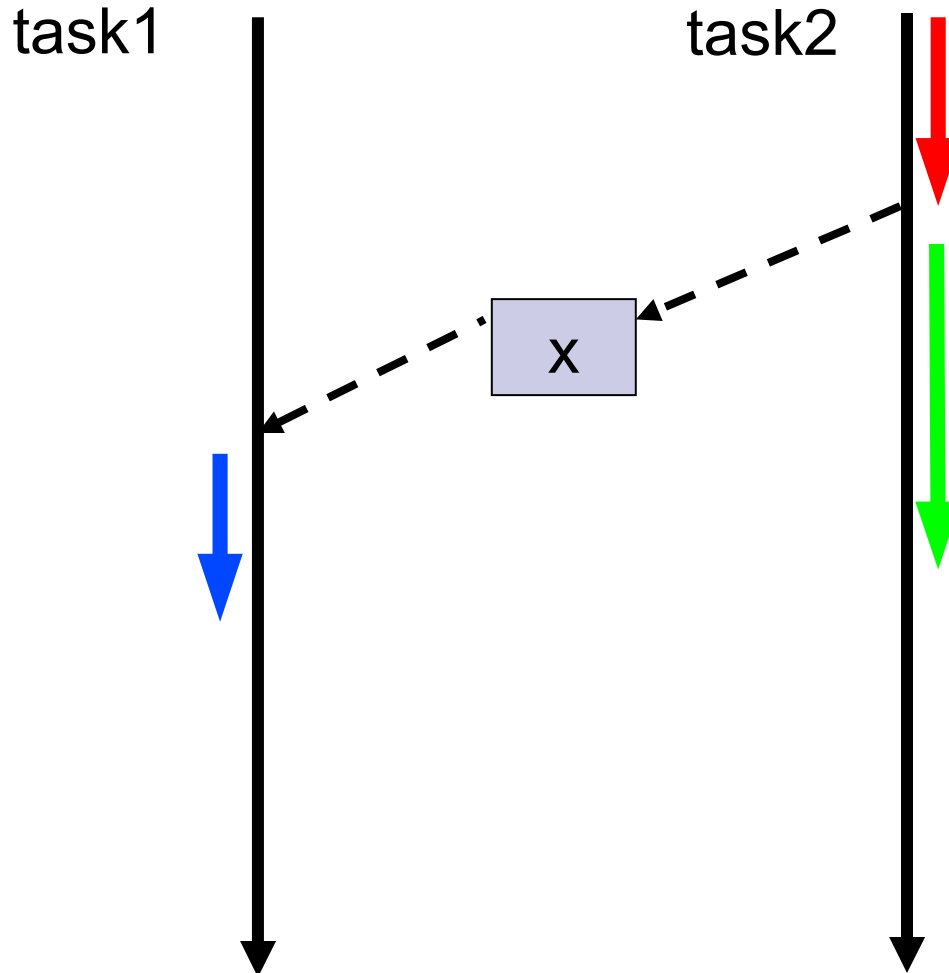
Deterministic deadlocks



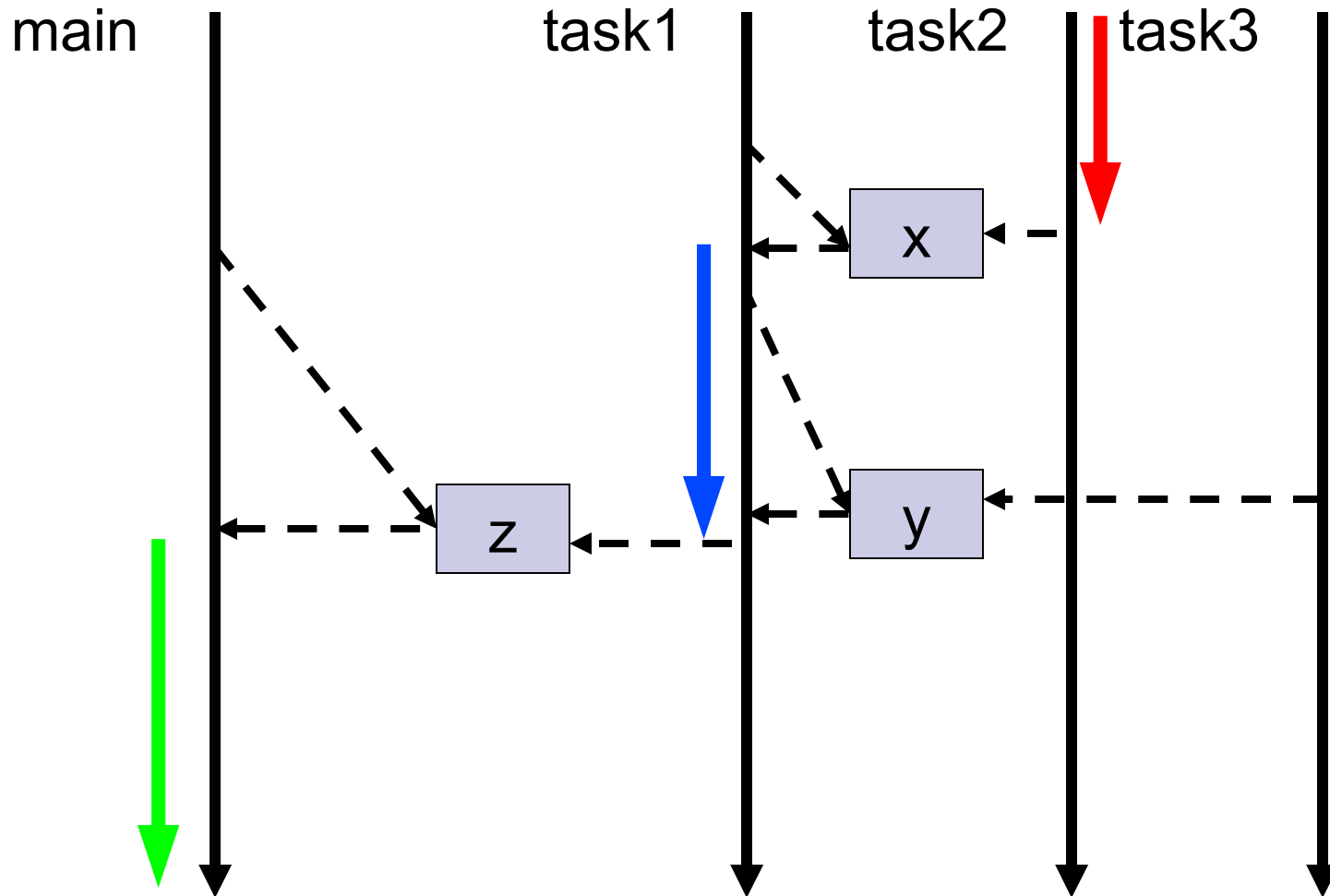
Dataflow Variables / Promises



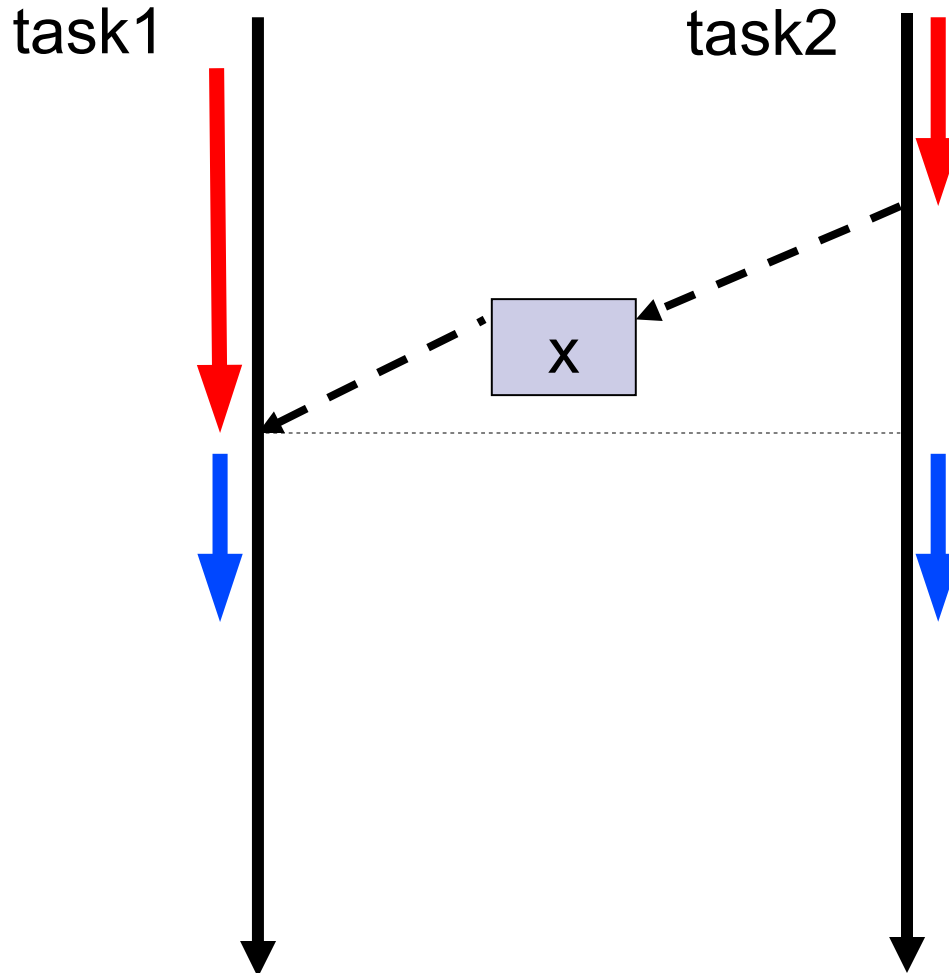
Dataflow Variables / Promises



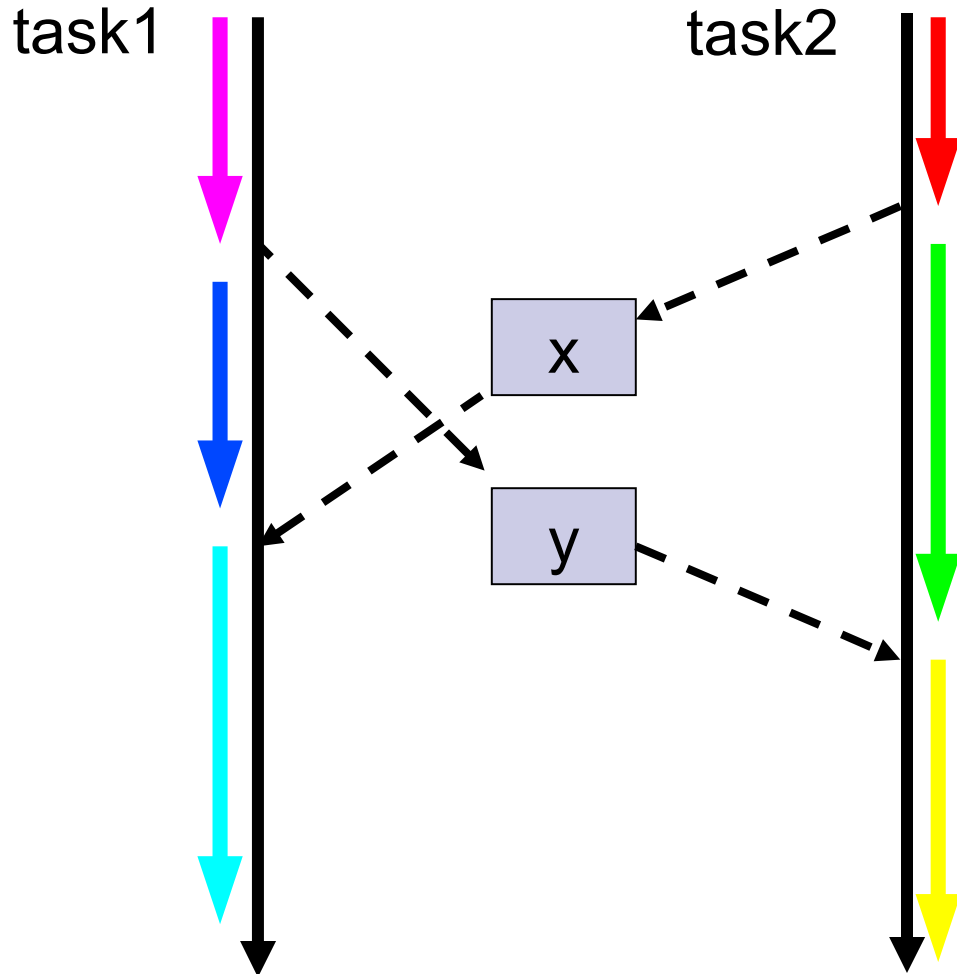
Dataflow Variables / Promises



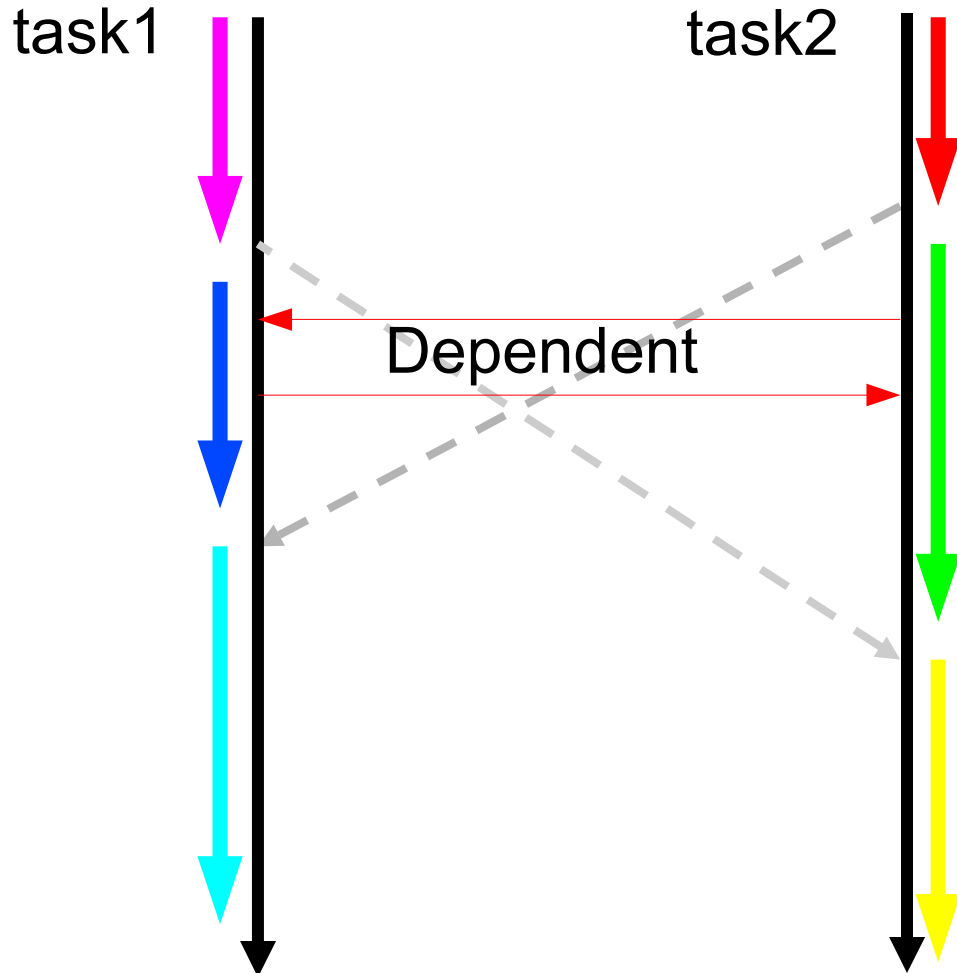
Synchronous Variables



Synchronous Variables



Synchronous Variables



Promises to exchange data

```
task { z << x.val + y.val }
```

```
task { x << 10 }
```

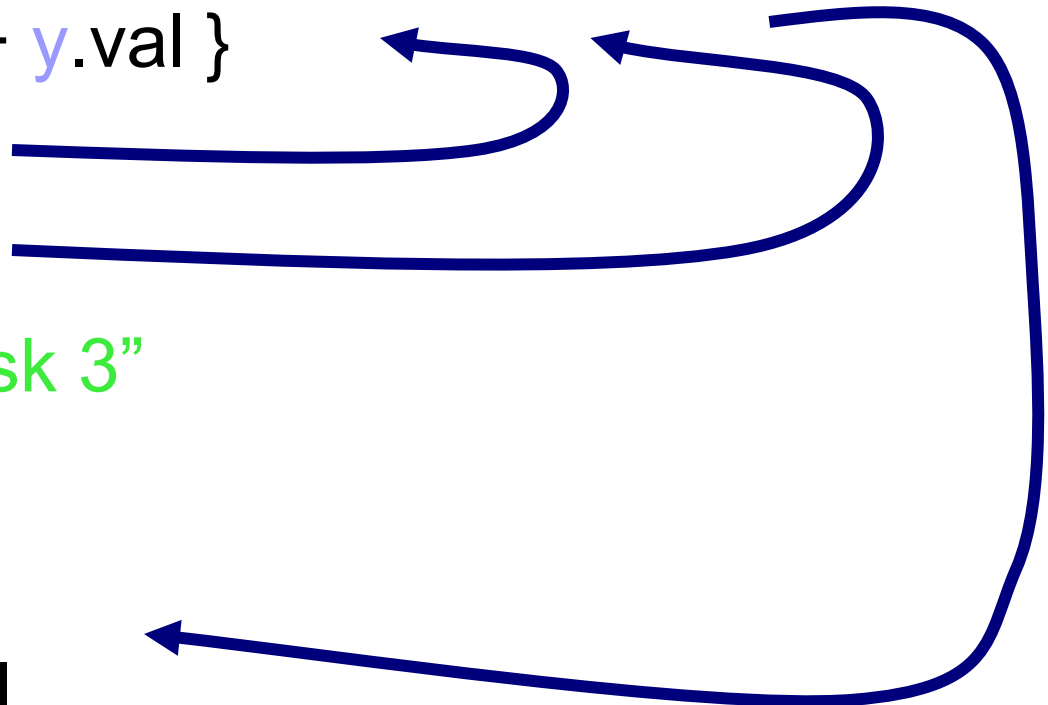
```
task {
```

```
    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);
```

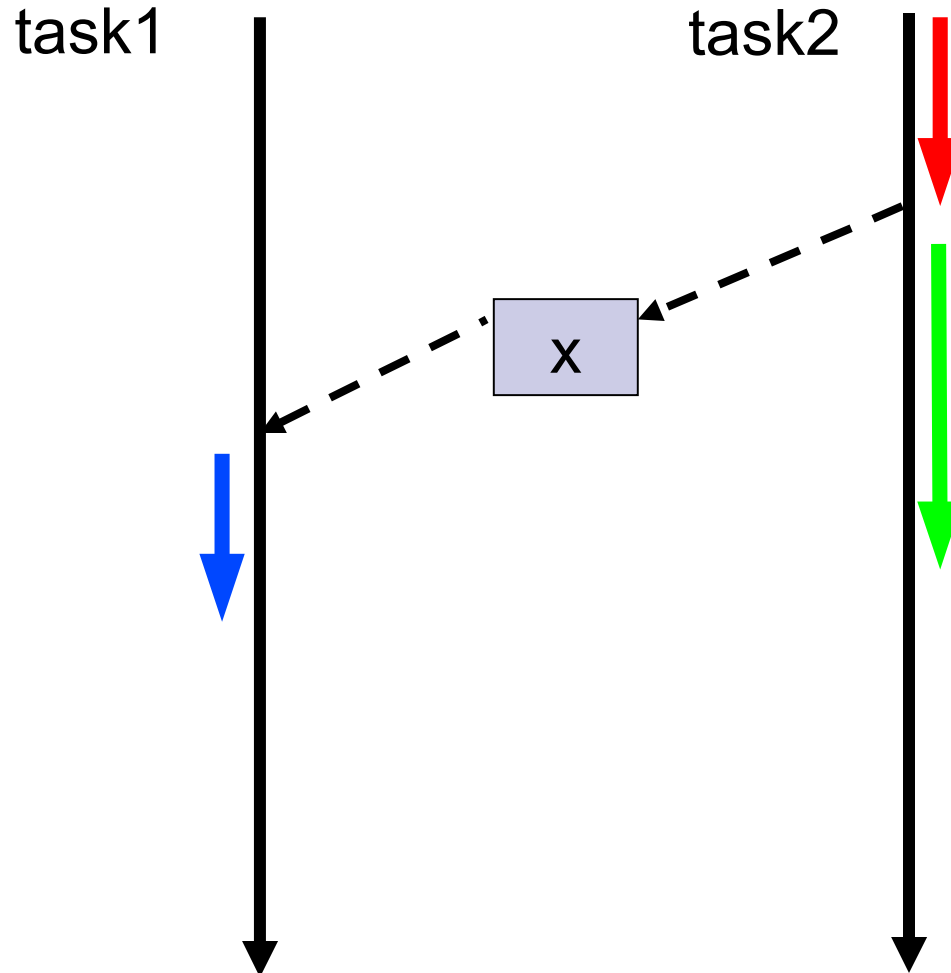


Lazy promises

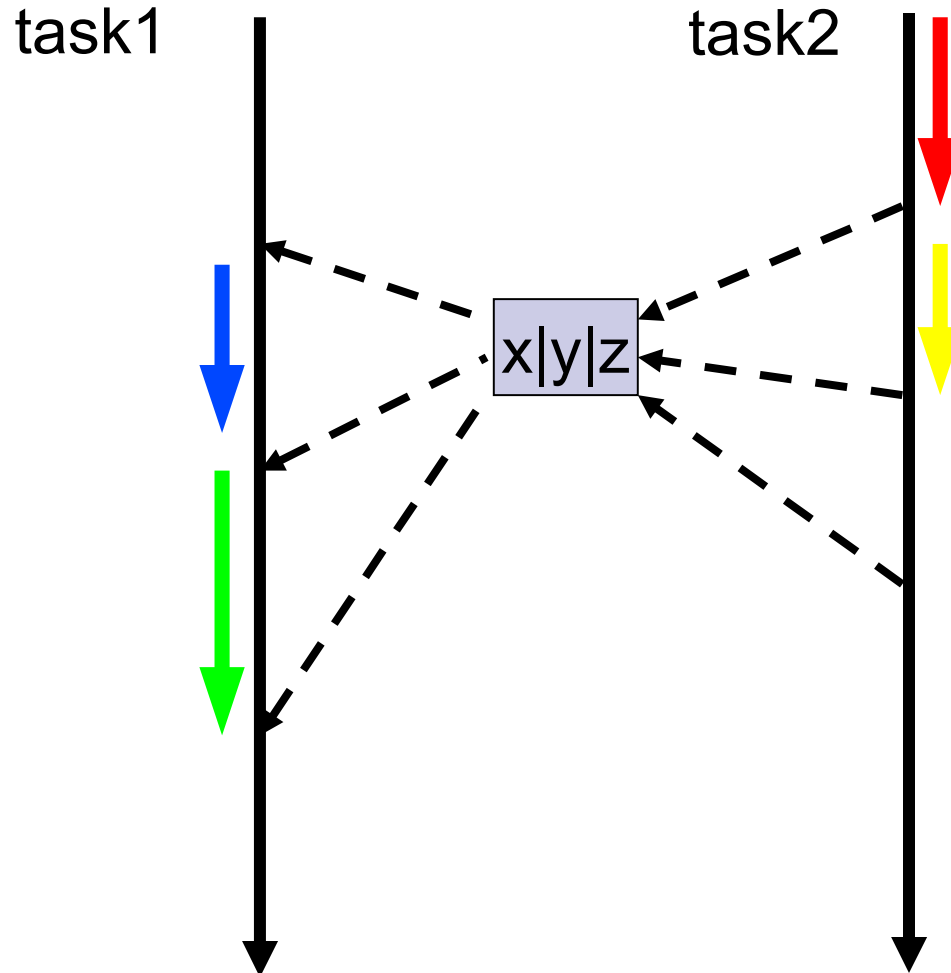
Only calculated when needed the first time

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

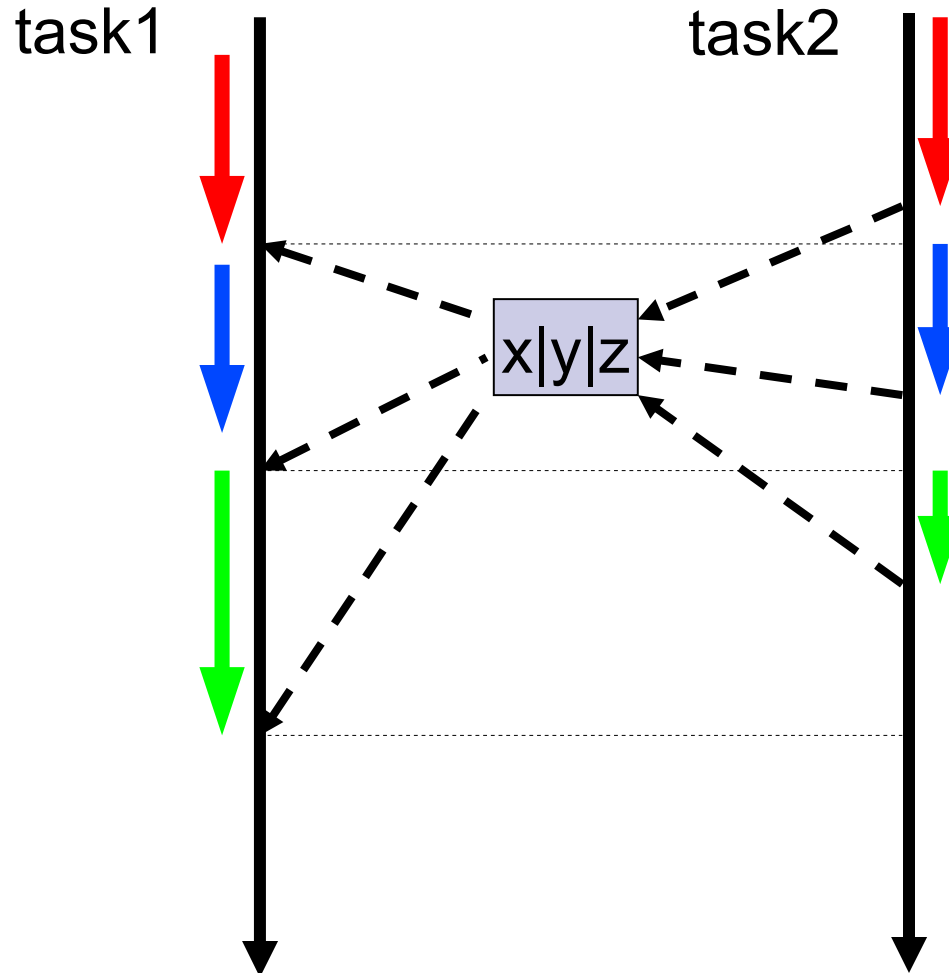
Dataflow Variables / Promises



Dataflow Channels



Synchronous Channels



Tasks with progress indication

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

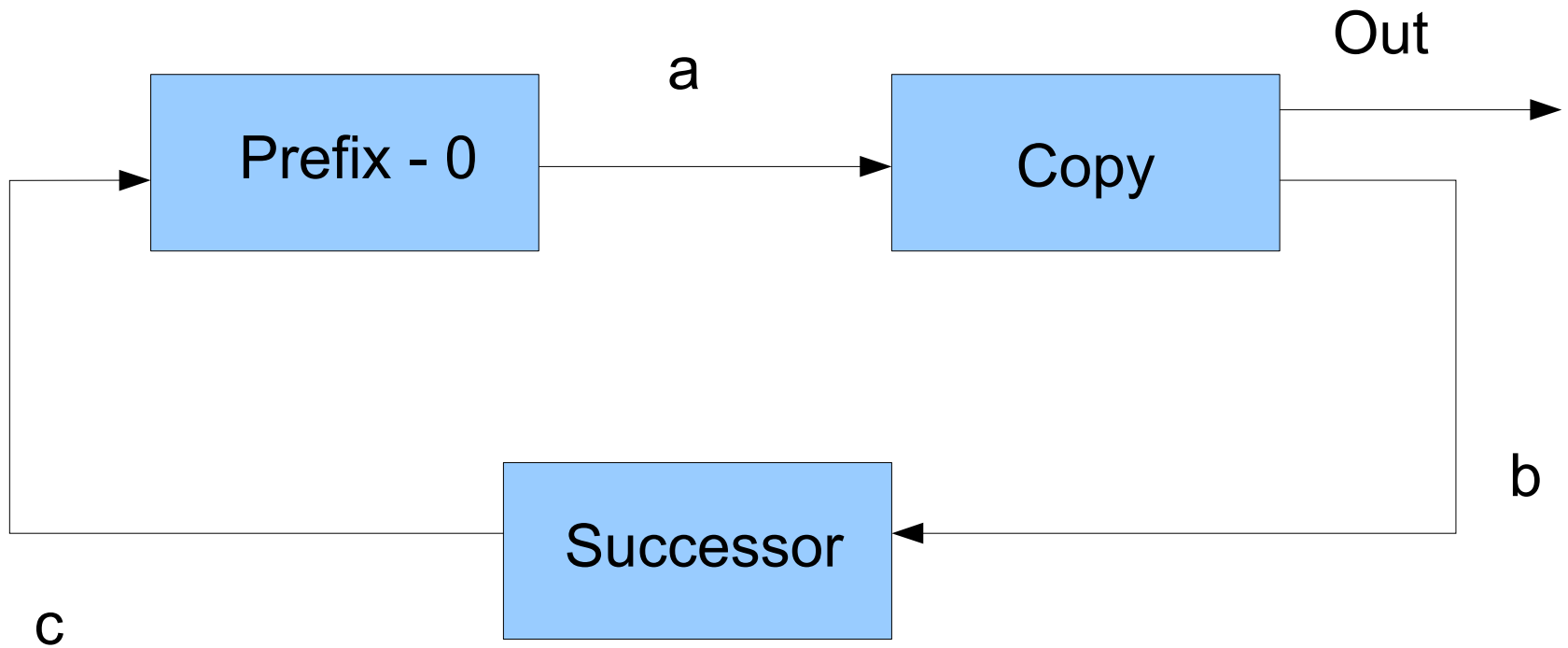



A CSP flavour

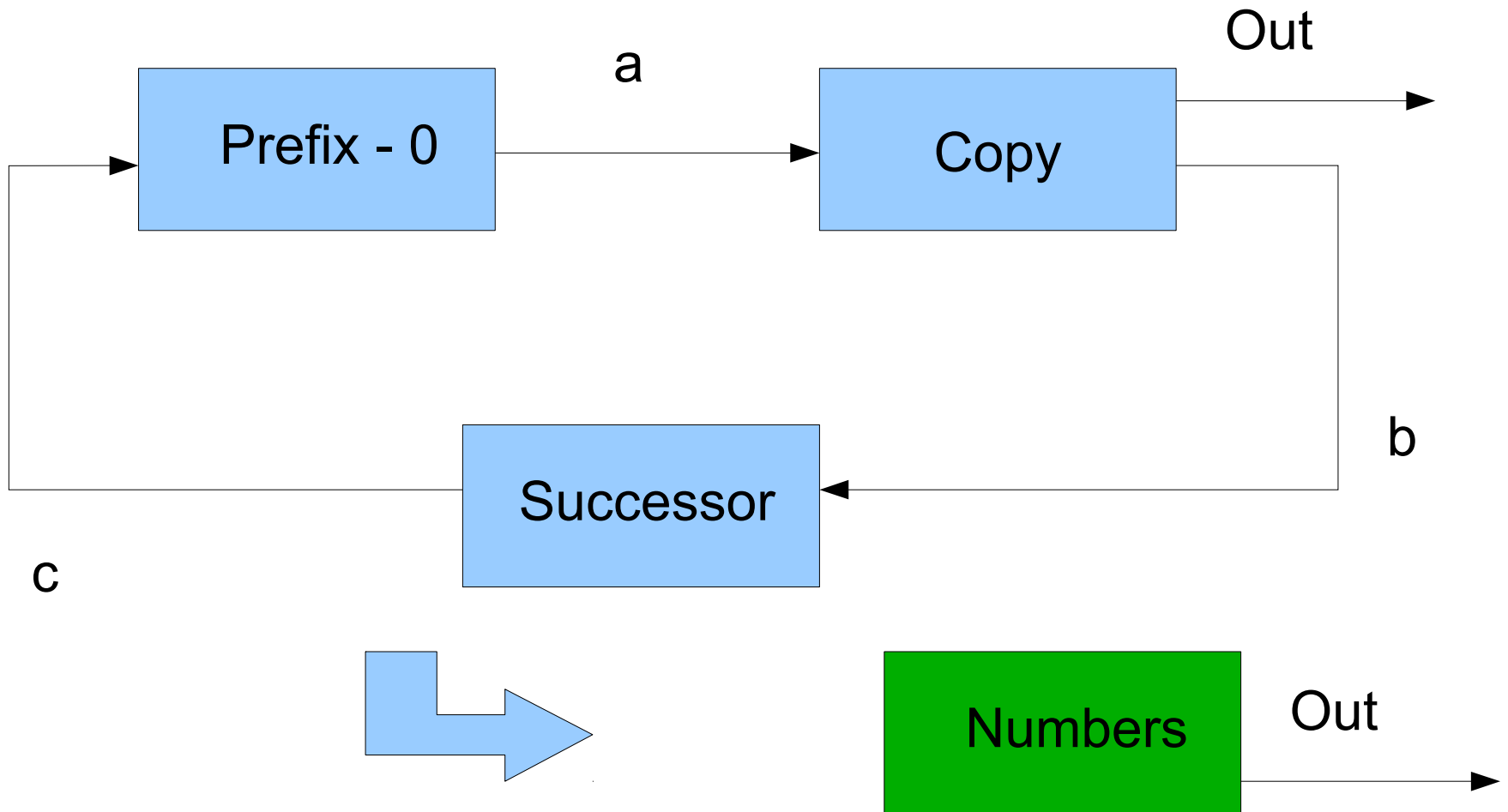
Communicating Sequential Processes

Focus on composable processes more than on data

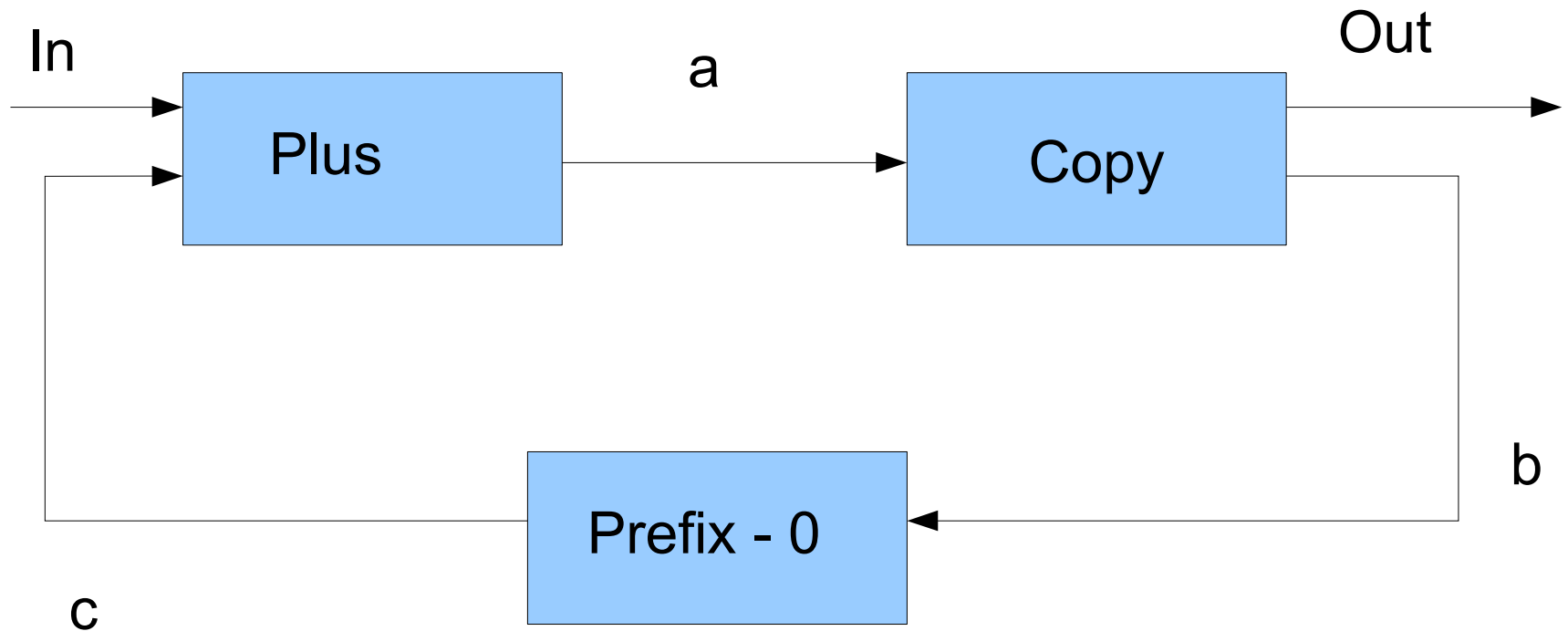
Processes



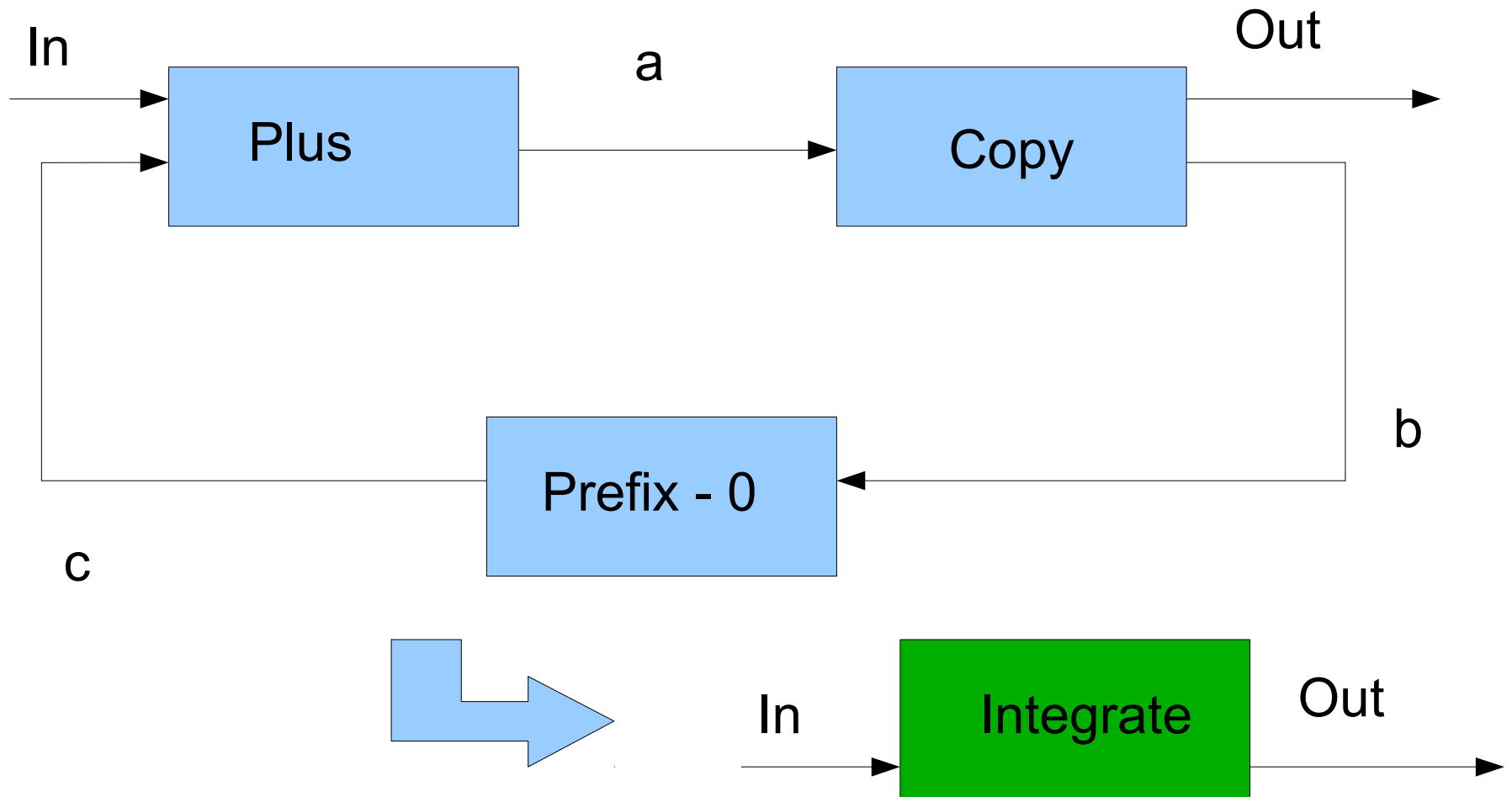
Processes



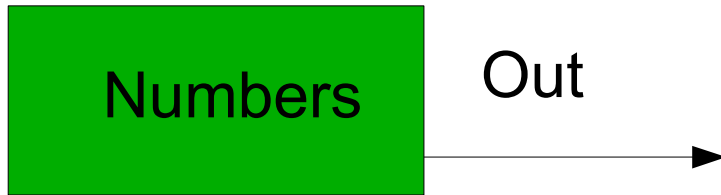
Processes



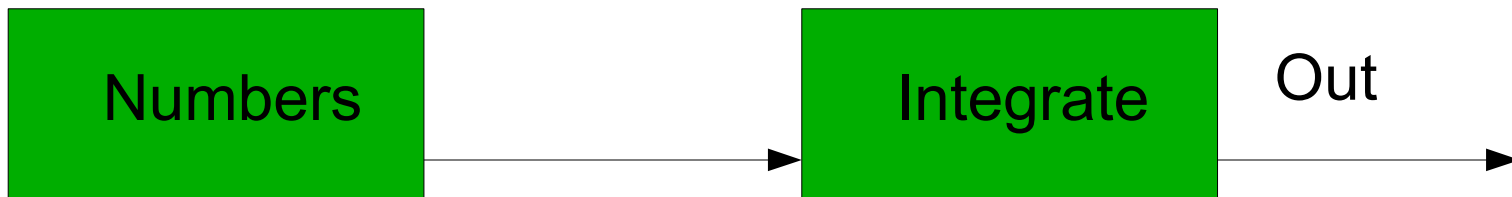
Processes



Processes

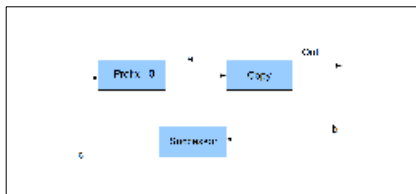


Processes

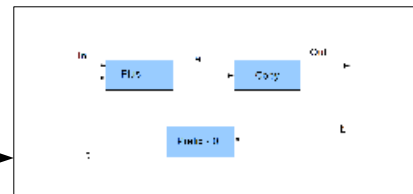


Processes

Numbers

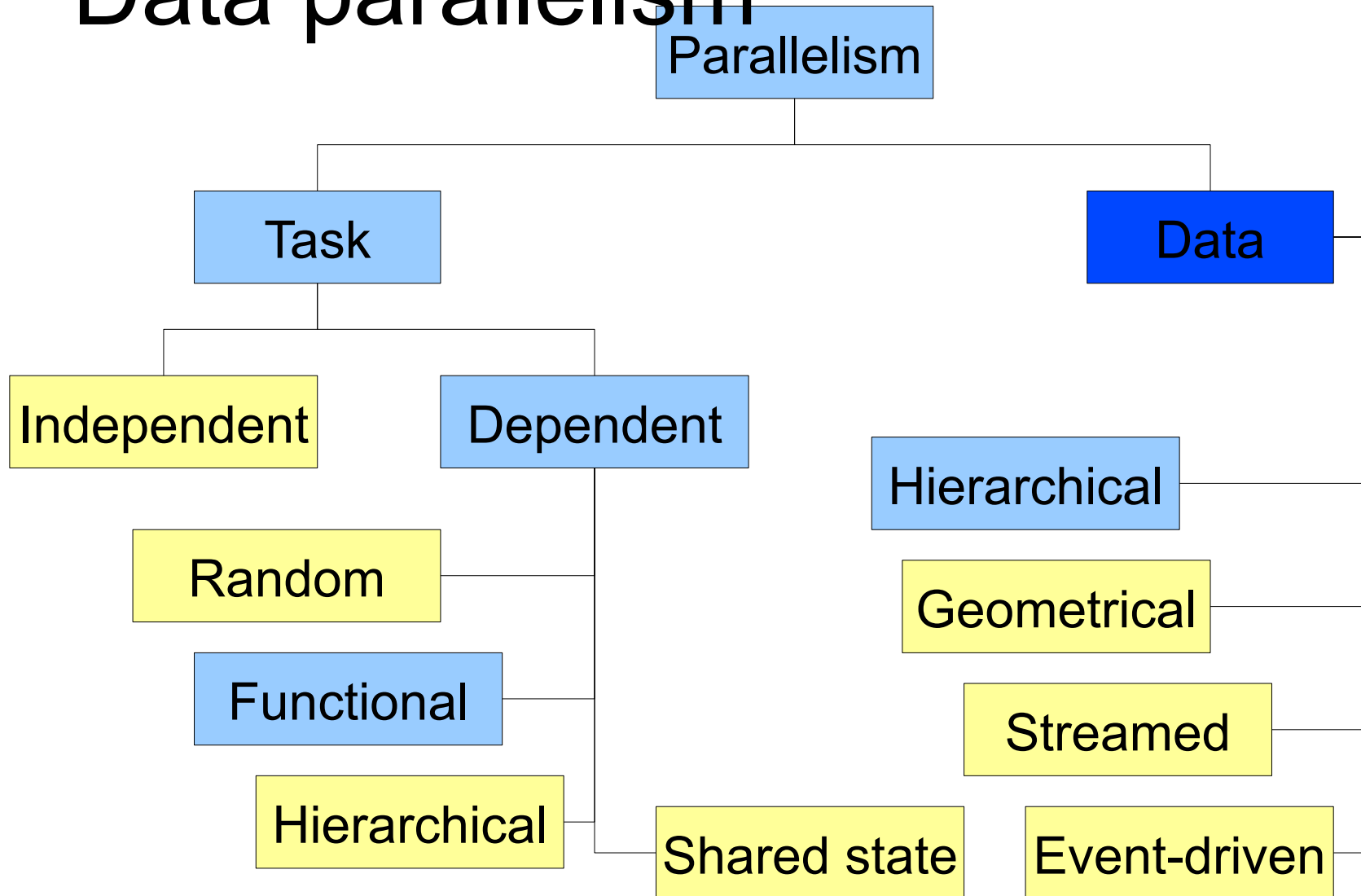


Integrate

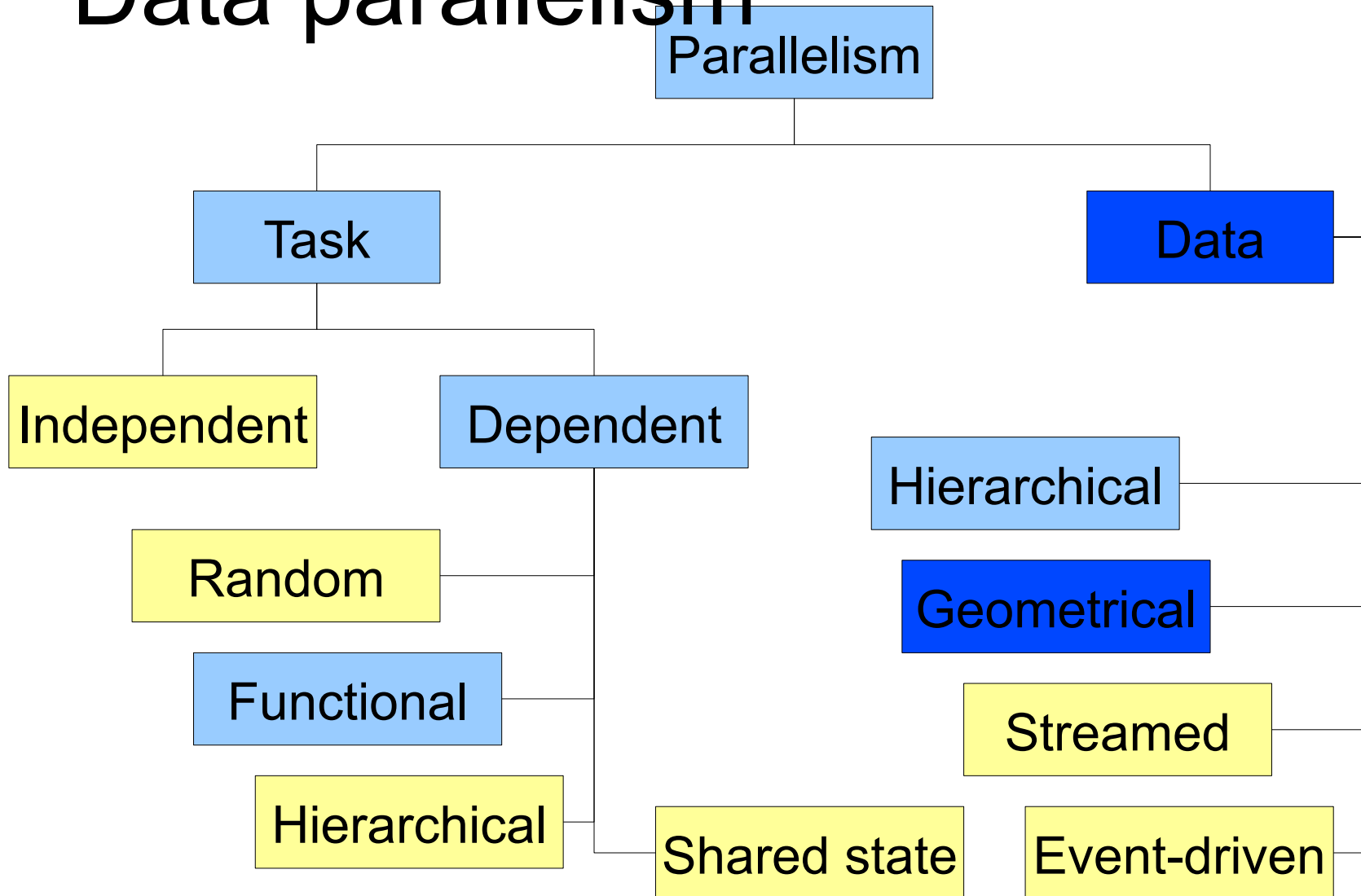


Out

Data parallelism



Data parallelism



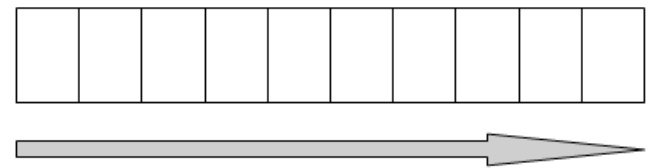
Geometric decomposition

`images.eachParallel {it.process()}`

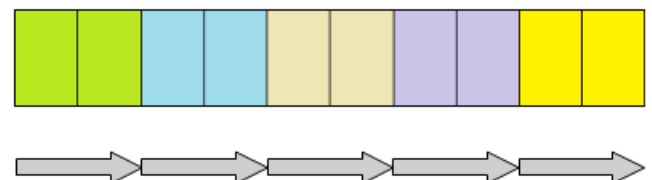
`documents.sumParallel()`

`candidates.maxParallel {it.salary}.marry()`

1 thread



5 threads



Geometric decomposition

```
registrations = submissions
```

```
  .collectParallel { form -> form.process() }
```

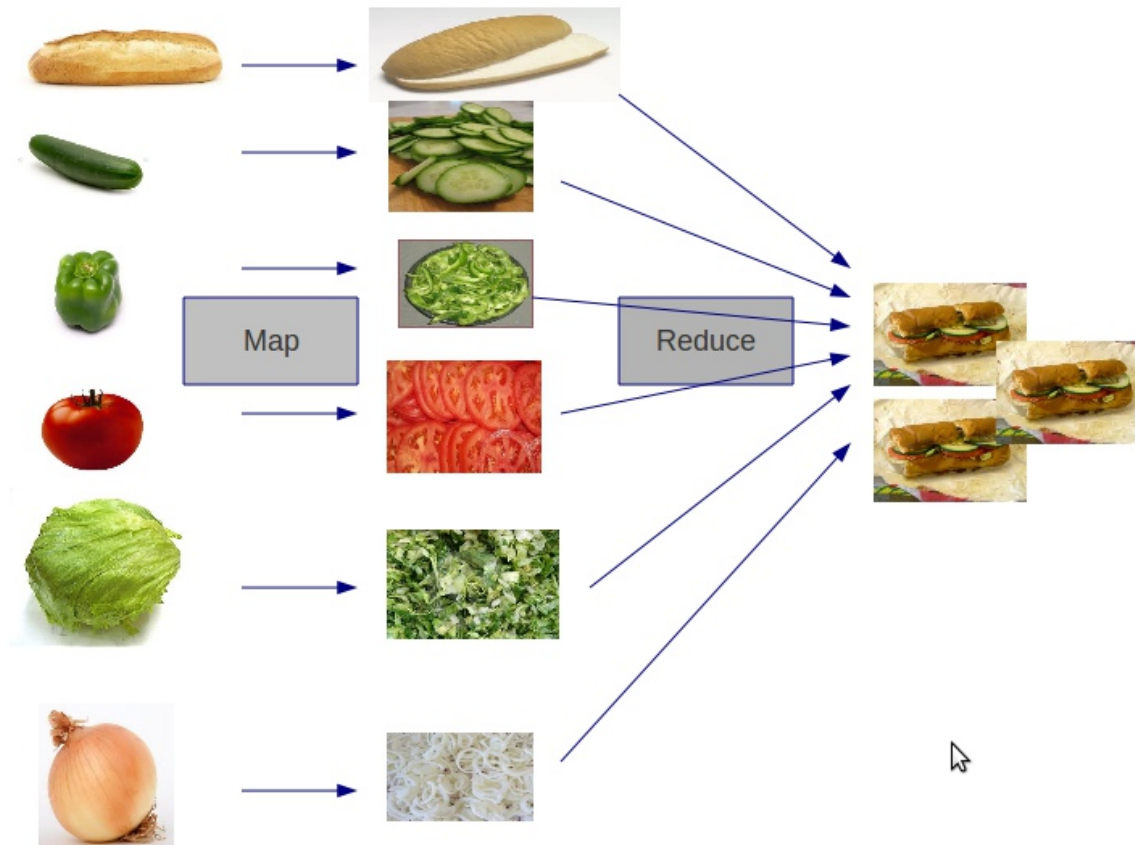
```
  .findAllParallel { it.valid }
```

```
registrations = submissions.parallel
```

```
  .map { form -> form.process() }
```

```
  .filter { it.valid }.collection
```

Map - reduce



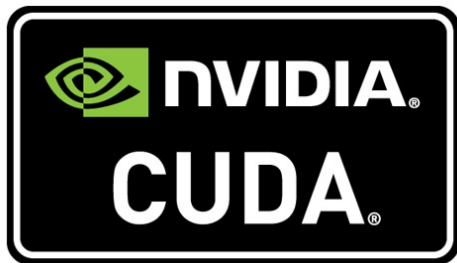
Frequent confusion

[Questions](#)[Tags](#)[Users](#)[Badges](#)[Unanswered](#)

parallel quick sort outdone by single threaded quicksort

- ▲ I've been reading , here is the example in the book using futures to implement parallel quick sort.
 - 0 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



Java watch list:

<https://github.com/pcpratts/rootbeer1/>

<http://openjdk.java.net/projects/sumatra/>



Improper use 1

```
def accumulator = 0
```

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


Improper use 2

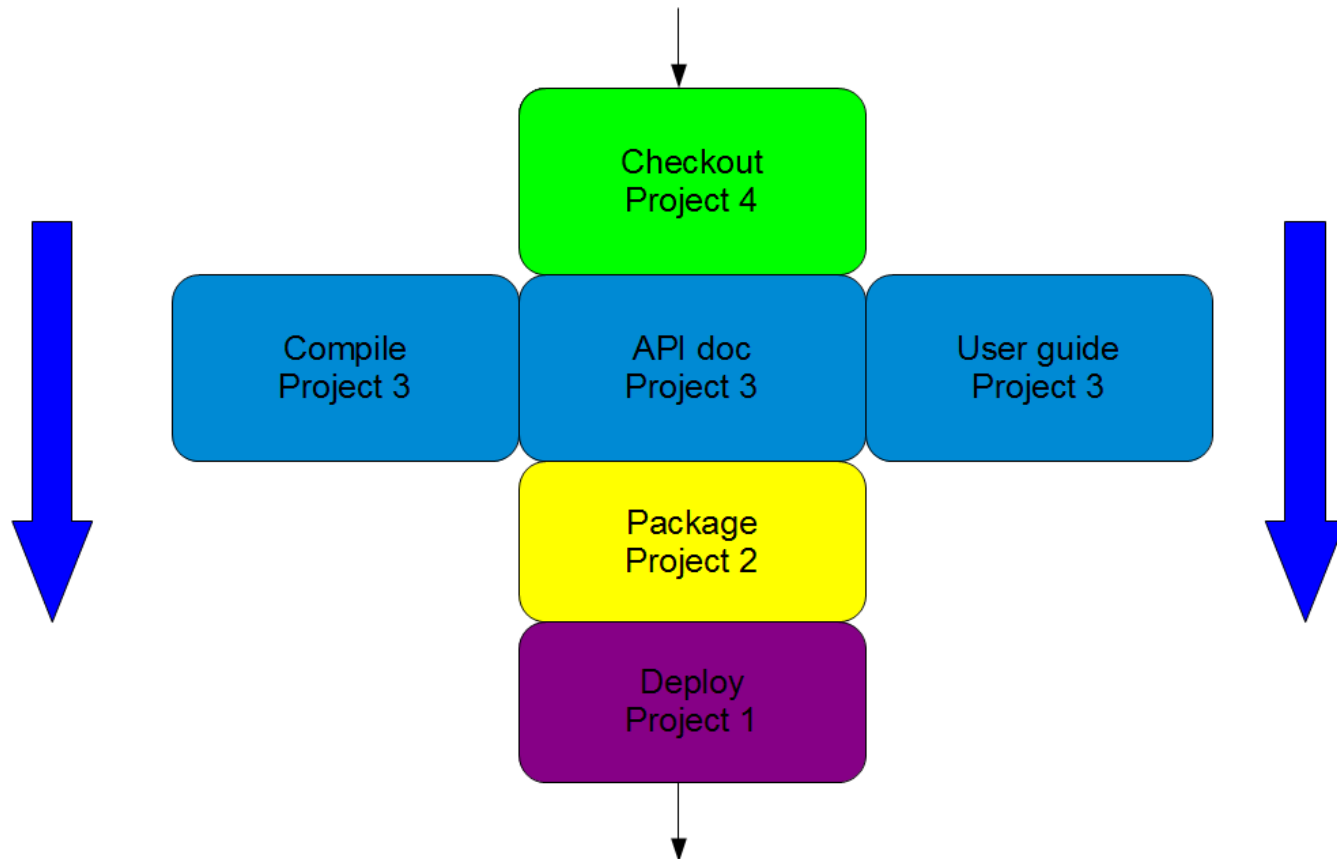
```
new File("/file.txt").withReader{reader ->
  reader.eachParallel {
    def r1 = step1(r)
    def r2 = step2(r1)
    def r3 = step3(r2)
  }
}
```

Unroll iteration

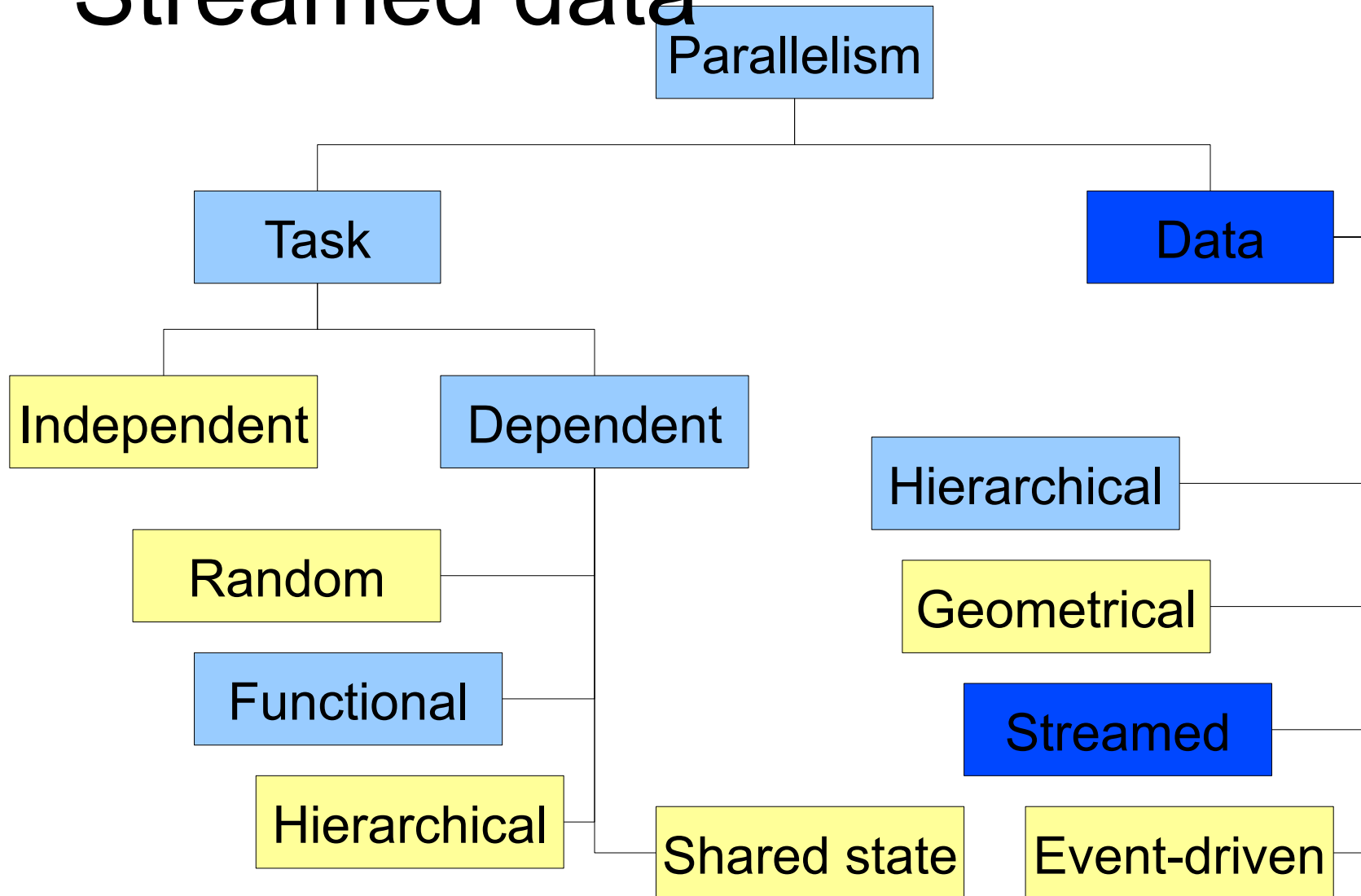
```
def pipeline = data | step1 | step2 | step3
```

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

Unroll iteration



Streamed data



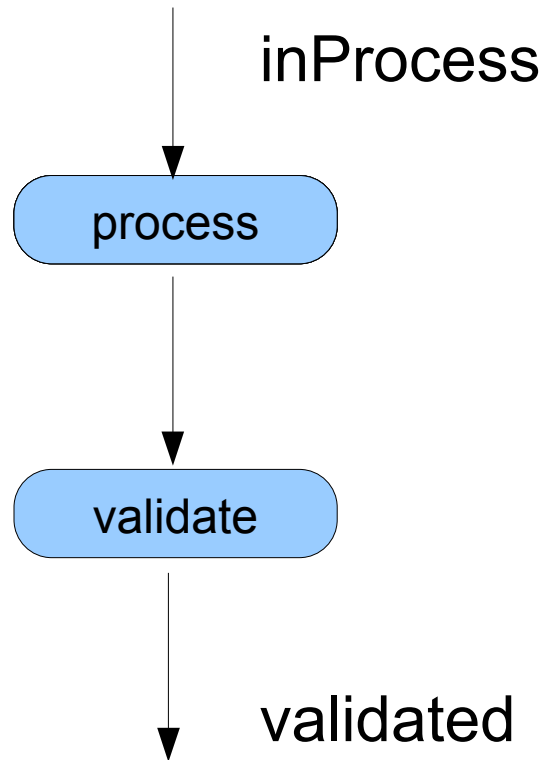
Pipeline DSL

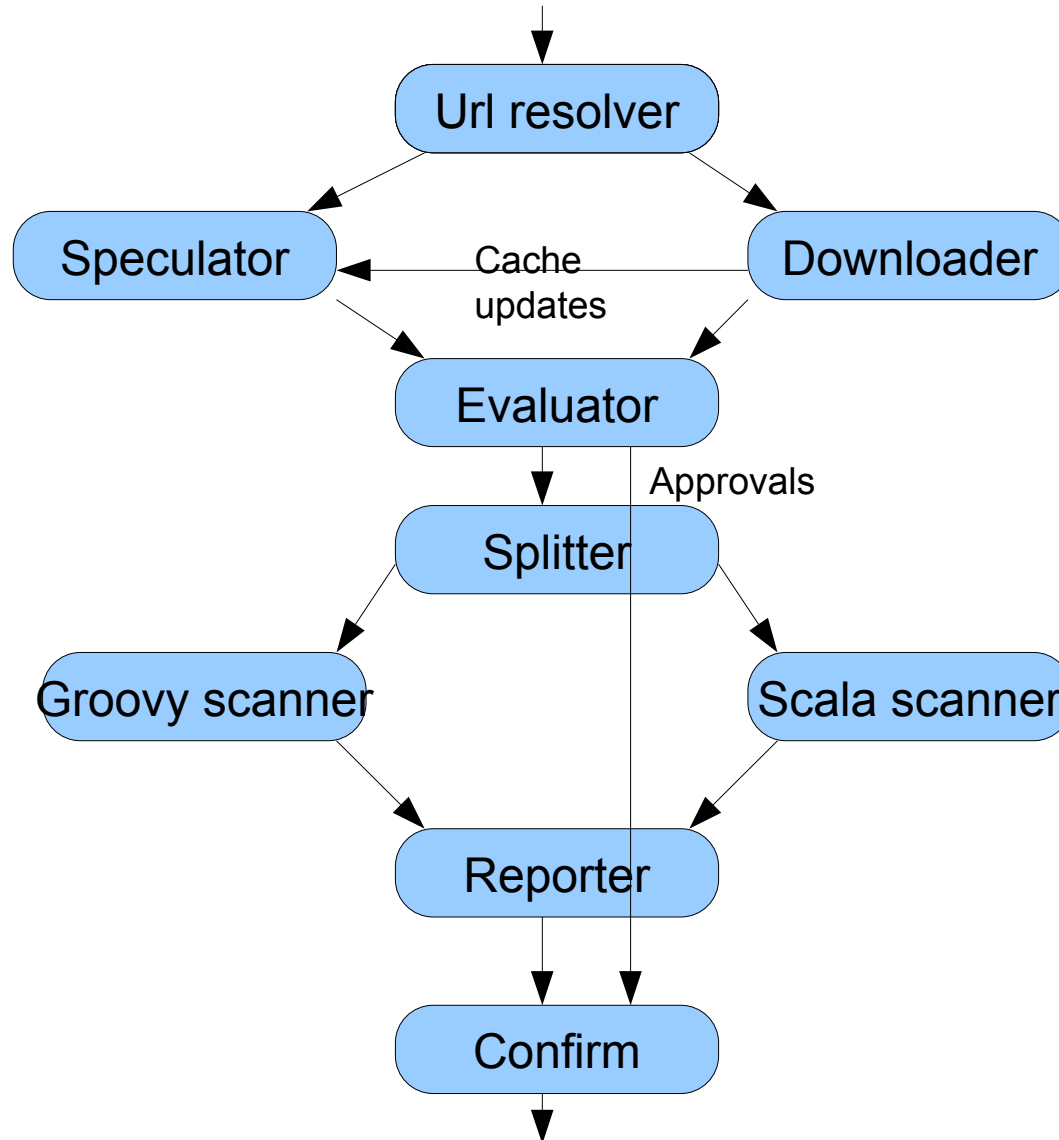
```
def toProcess = new DataflowQueue()
```

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

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

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







Dataflow Operators

```
operator(inputs: [headers, bodies, footers],  
         outputs: [articles, summaries])
```

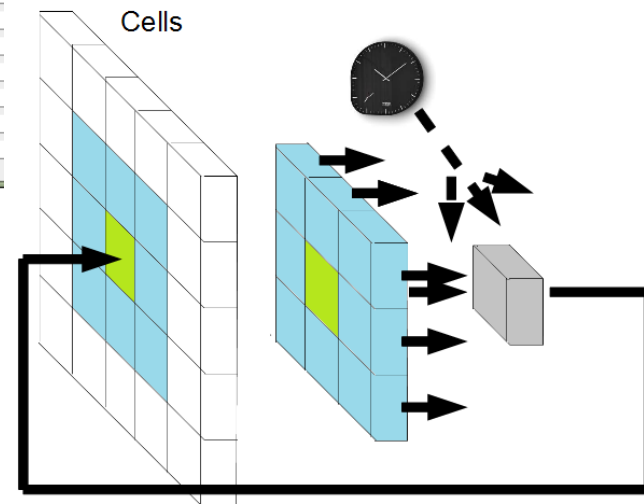
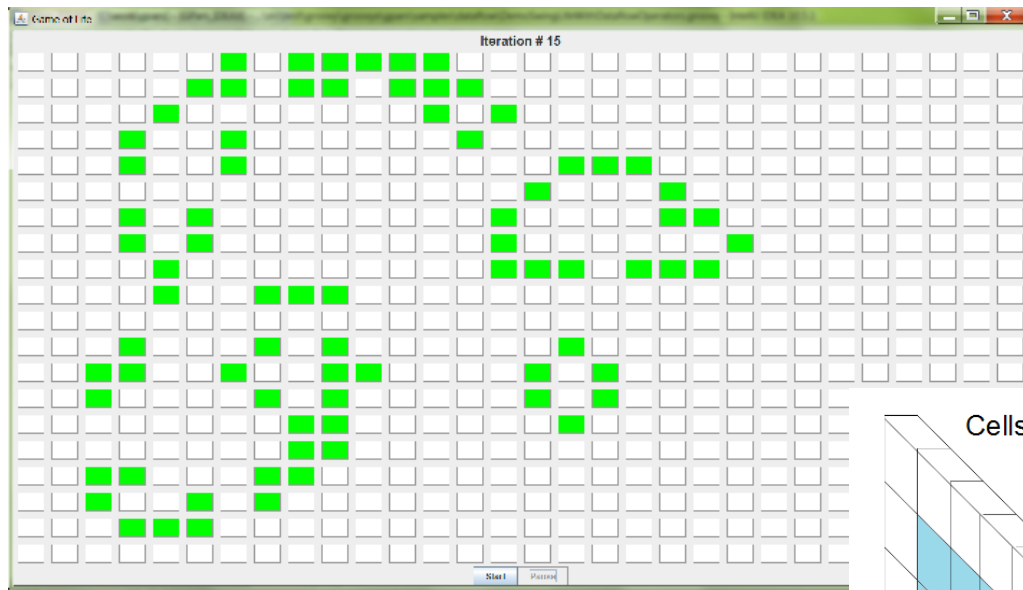
```
{header, body, footer ->
```

```
  def article = buildArticle(header, body, footer)
```

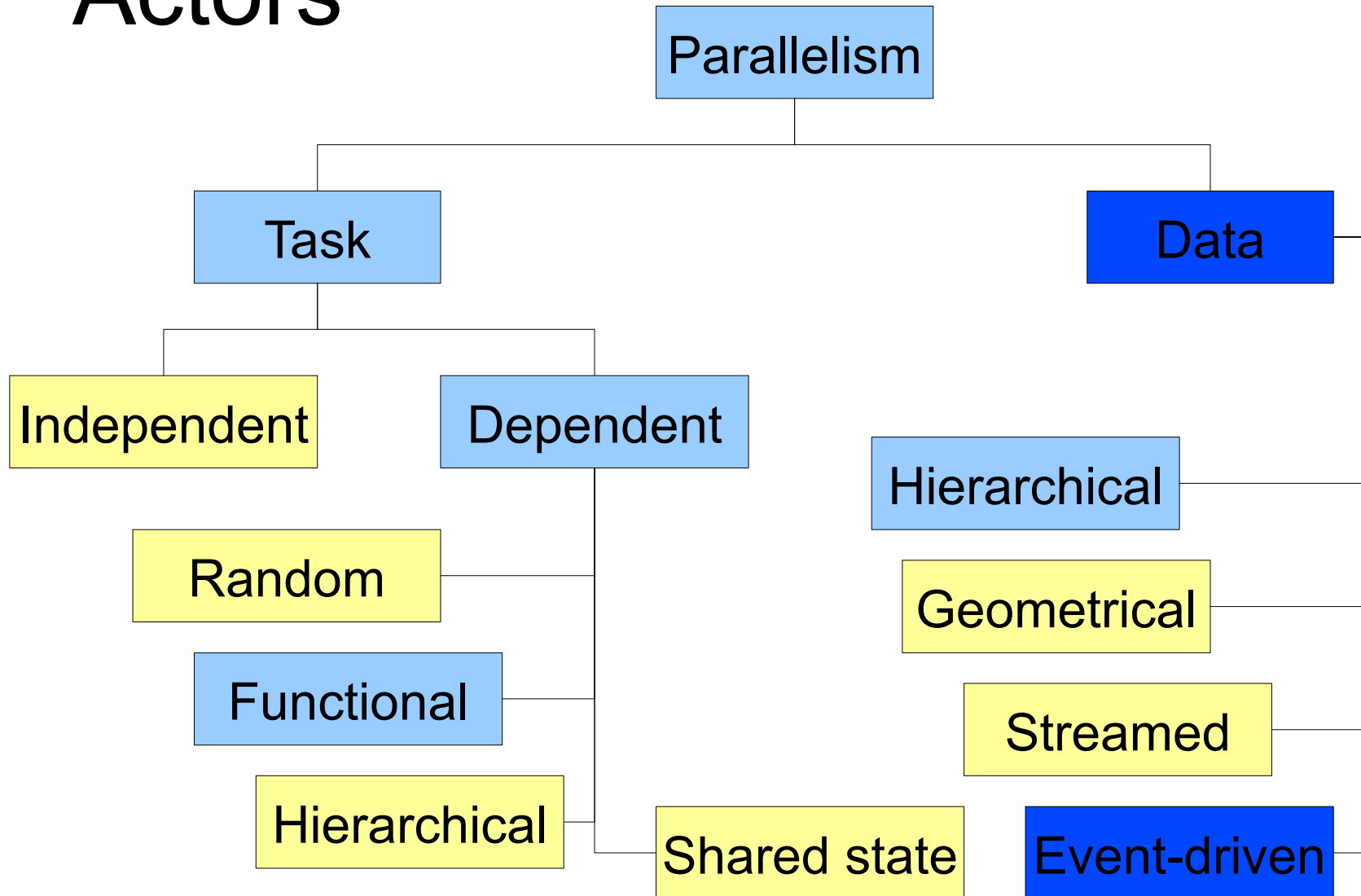
```
  bindOutput(0, article)
```

```
  bindOutput(1, buildSummary(article))
```

```
}
```

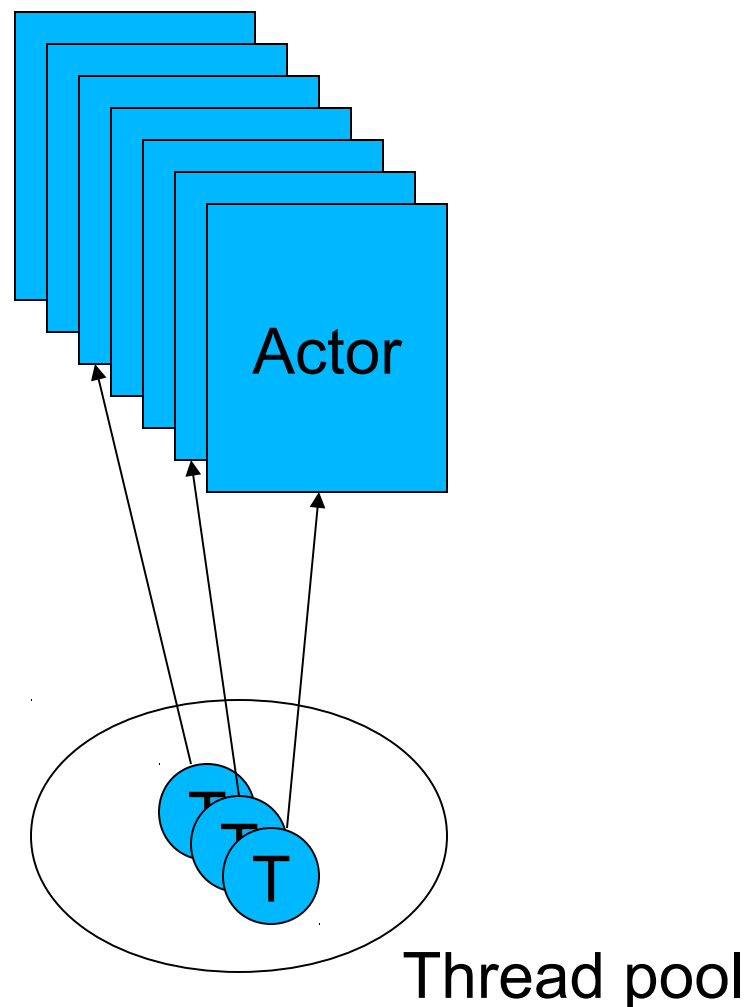



Actors

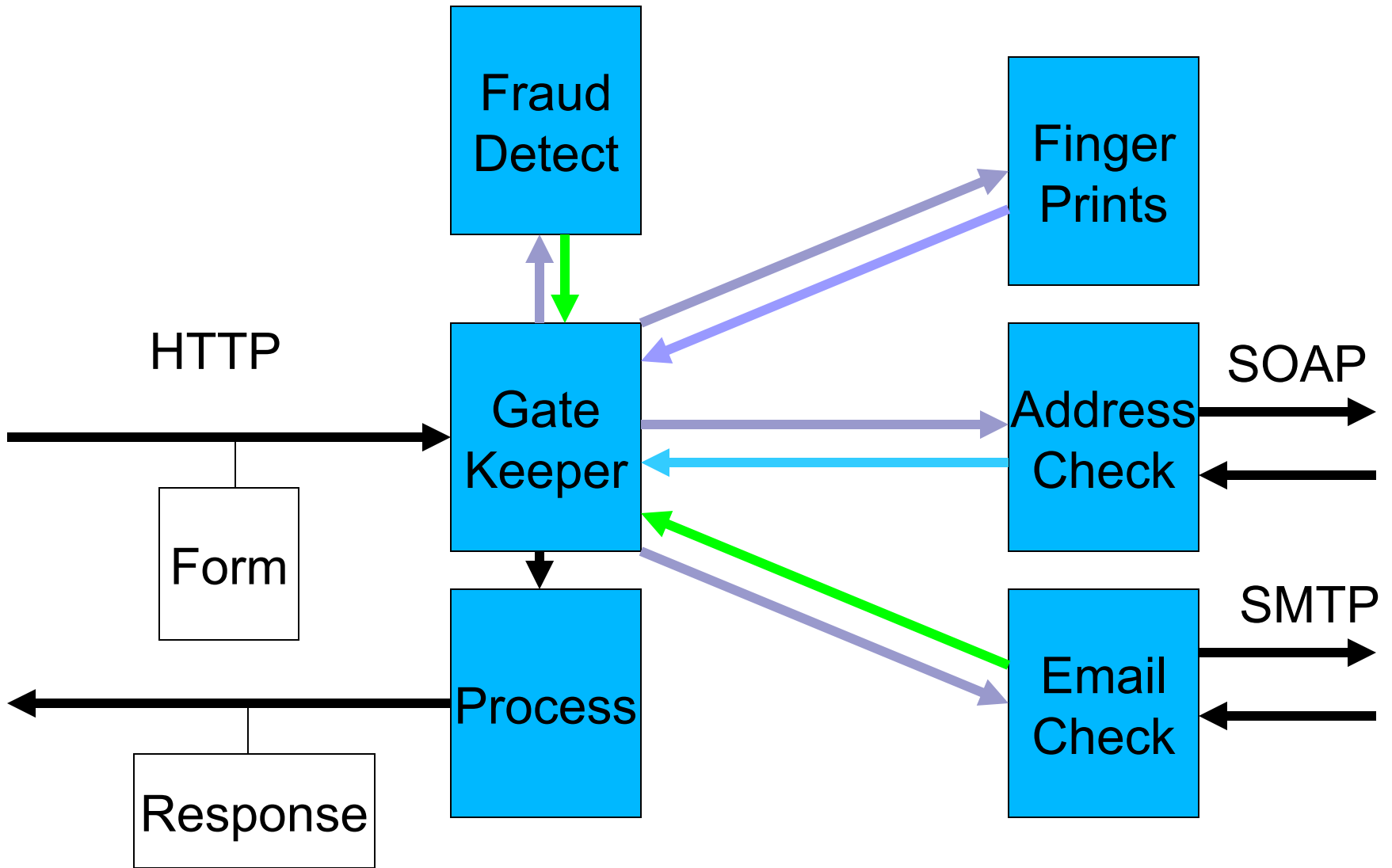


Actors

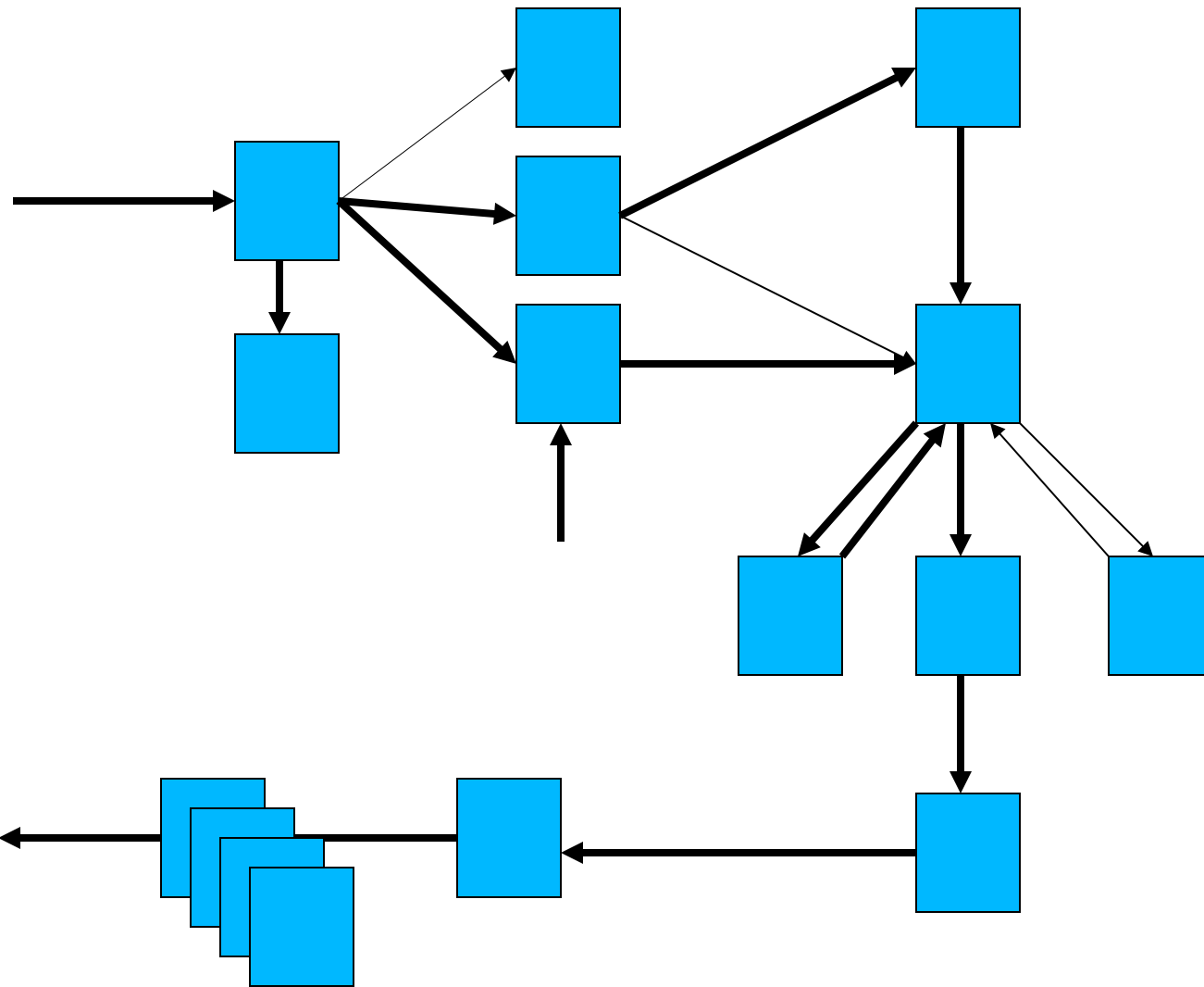
- Isolated
- Communicating
 - Immutable messages
- Active
 - Pooled shared threads
- Activities
 - Create a new actor
 - Send a message
 - Receive a message



Actors use



Actors patterns



Enricher

Router

Translator

Endpoint

Splitter

Aggregator

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

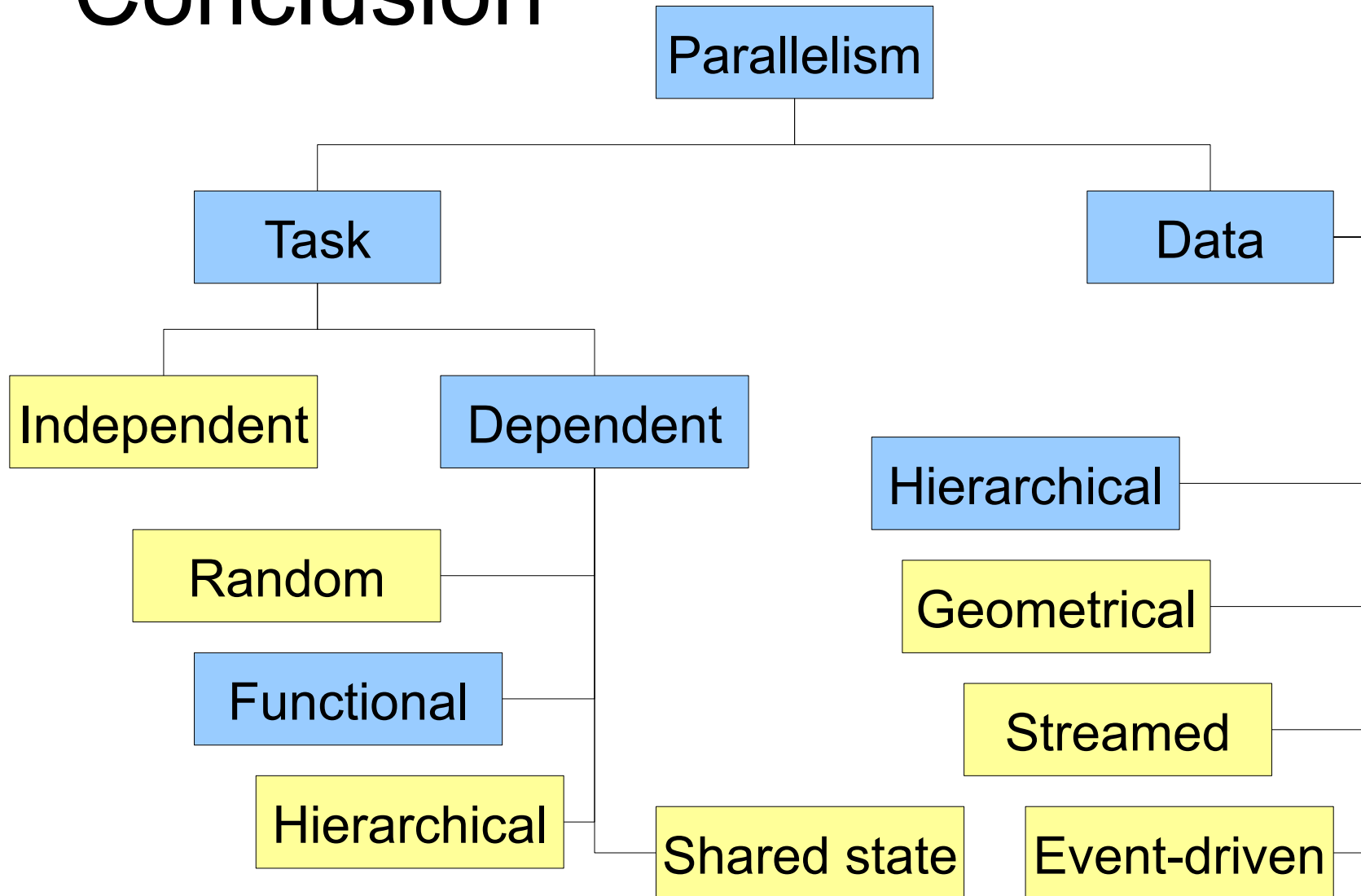
@ActiveObject

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

@ActiveMethod

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


Conclusion





Summary

Parallelism is not hard, multi-threading is

Jon Kerridge, Napier University

Questions?

Find more at:

<http://gpars.org>

<http://www.jroller.com/vaclav>

http://twitter.com/vaclav_pech

