Principles of Software Construction: Objects, Design and Concurrency

The Perils of Concurrency, part 3

Can't live with it.
Can't live without it.

15-214

toad

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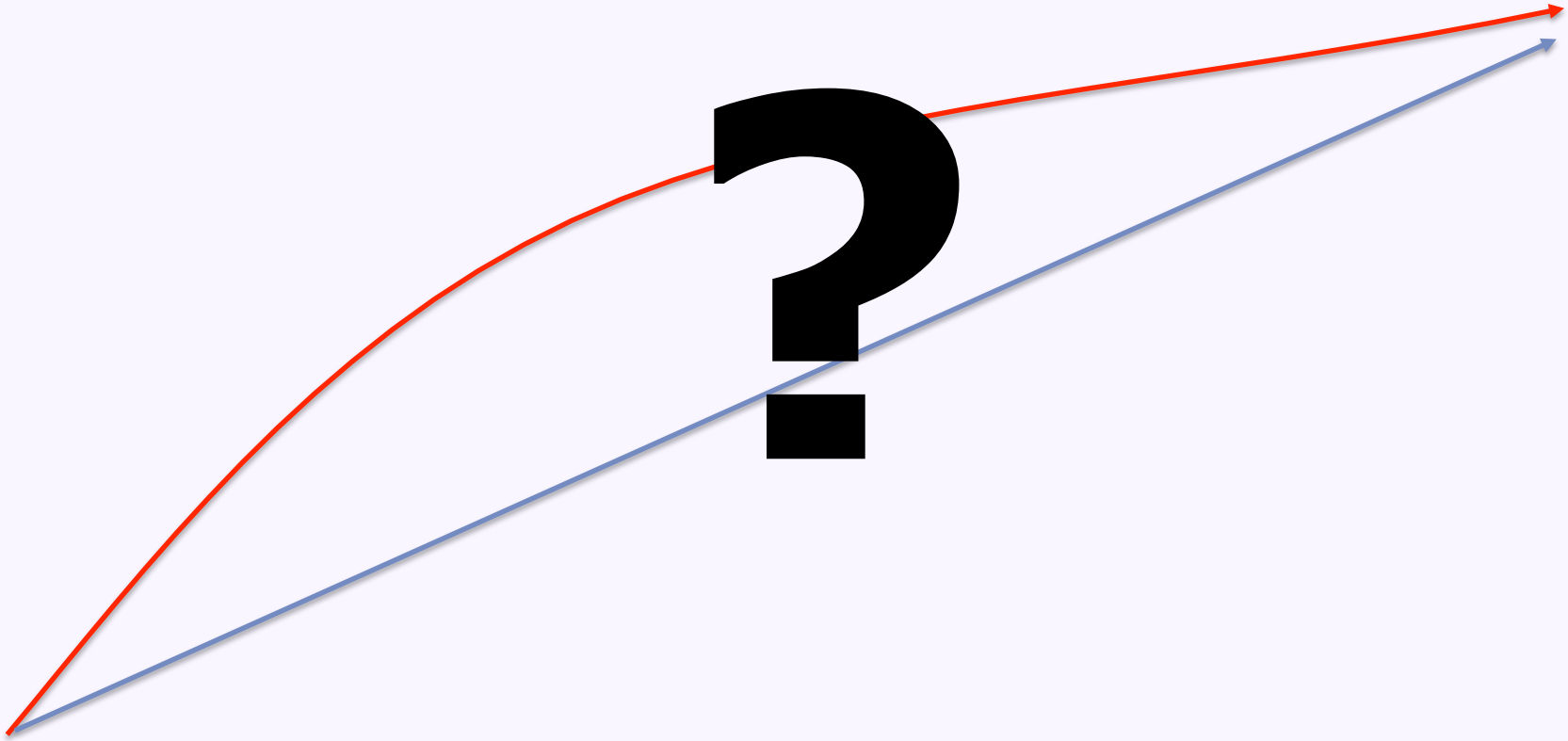
Administrivia

- Problems with your Homework 6 partner?
  - Email me and/or Jonathan
- Homework 6c code due tonight
  - Using a late day allows you to turn in the second part of hw6c late, and also lab 7 late

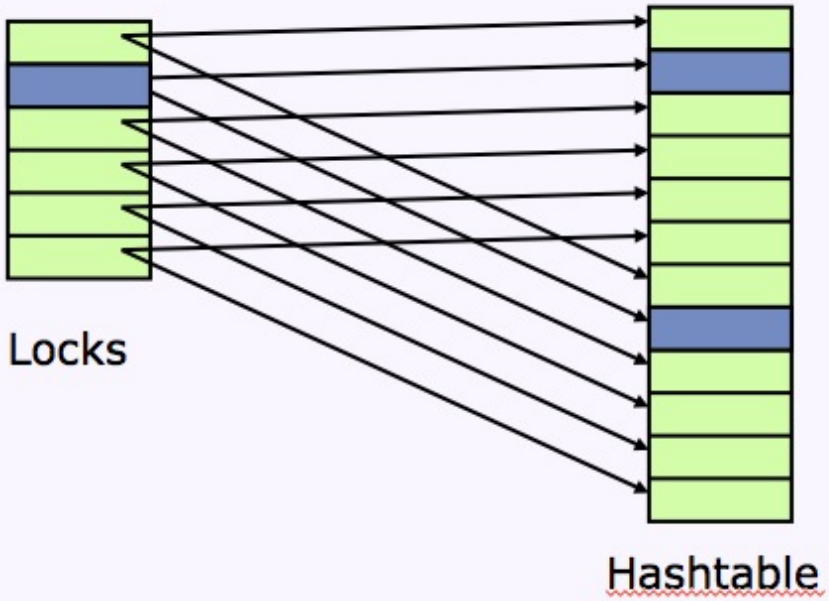
Last time: Static analysis and JSure

- Annotate design intent for concurrent programs
- Aside: redundancy and robustness



Before that: concurrency

- Basic concurrency in Java
  - Primitive concurrency control mechanisms
- Race conditions
  - check-then-act
- Deadlock
- Livelock

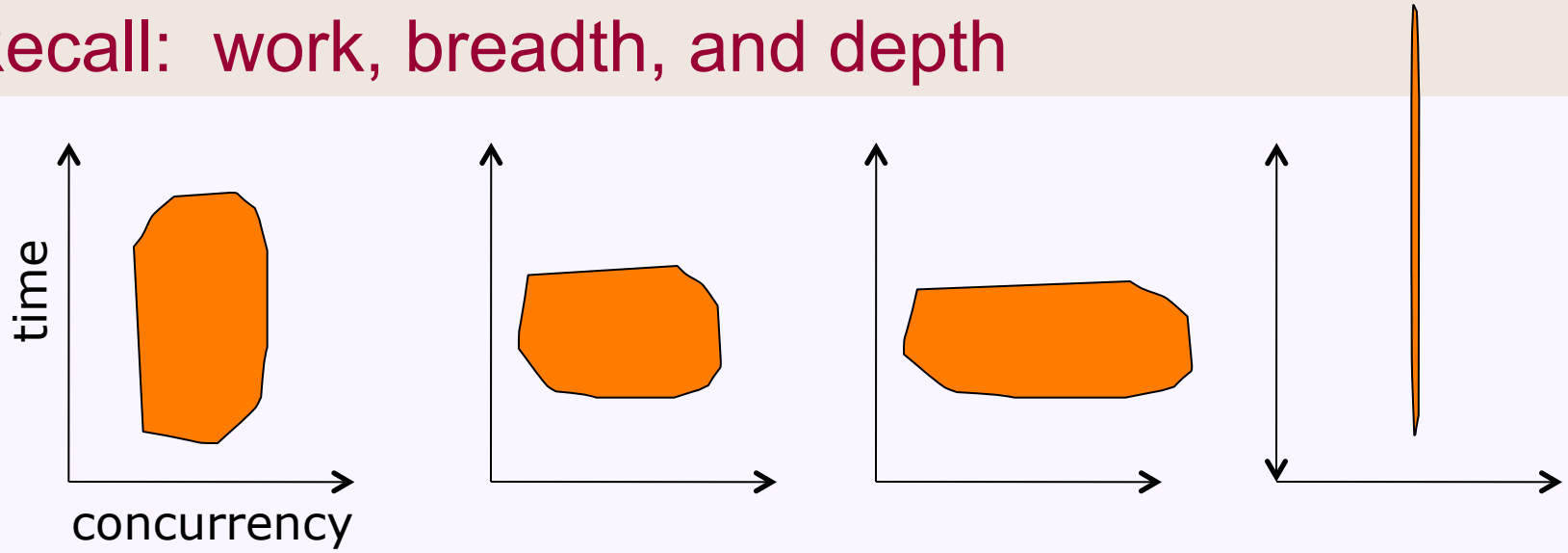


`java.util.concurrent.ConcurrentHashMap`

Today: Concurrency, part 3

- Higher-level languages, briefly
- Potpourri of parallel algorithms
- Distributed map-reduce frameworks

Recall: work, breadth, and depth



- Work: total effort required
  - area of the shape
- Breadth: extent of simultaneous activity
  - width of the shape
- Depth (or span): length of longest computation
  - height of the shape

Concurrency at the language level

- Consider:

```
int sum = 0;
Iterator i = list.iterator();
while (i.hasNext()) {
    sum += i.next();
}
```

- In python:

```
sum = 0;
for item in lst:
    sum += item
```

Parallel quicksort in Nesl

```
function quicksort(a) =
  if (#a < 2) then a
  else
   let pivot   = a[#a/2];
       lesser  = {e in a| e < pivot};
       equal   = {e in a| e == pivot};
       greater = {e in a| e > pivot};
       result  = {quicksort(v): v in [lesser,greater]};
   in result[0] ++ equal ++ result[1];
```

- Operations in {} occur in parallel
- What is the total work? What is the depth?
  - What assumptions do you have to make?

Prefix sums (a.k.a. inclusive scan)

- Goal: given array `x[0…n-1]`, compute array of the sum of each prefix of `x`

```
[ sum(x[0…0]),
  sum(x[0…1]),
  sum(x[0…2]),
  …
  sum(x[0…n-1]) ]
```

- e.g., `x = [13, 9, -4, 19, -6, 2, 6, 3]`

  prefix sums: `[13, 22, 18, 37, 31, 33, 39, 42]`

Parallel prefix sums

- Intuition: If we have already computed the partial sums `sum(x[0…3])` and `sum(x[4…7])`, then we can easily compute `sum(x[0…7])`
- Code:

```
prefix_sums(x):
  for d in 0 to (lg n)-1:              // d is depth
    parallelfor i in 2^d to n-1:
      newx[i] = x[i-2^d] + x[i]
    x = newx
```

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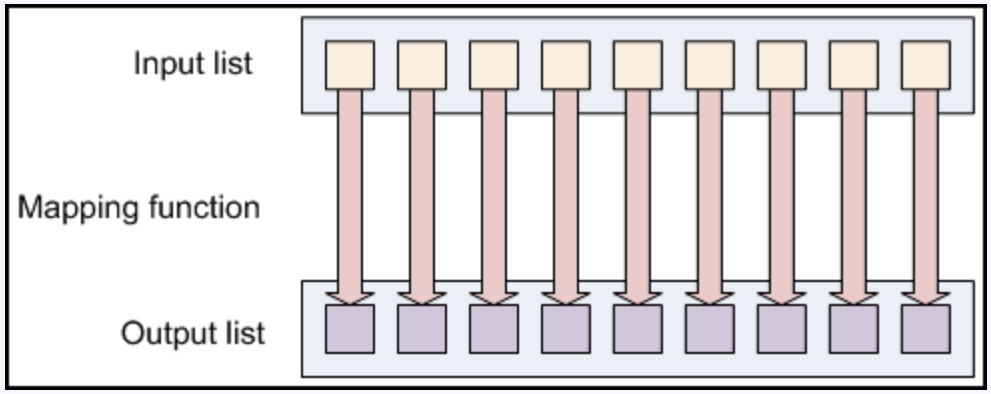
Map

- `map(f, x[0…n-1])`
  - Apply the function `f` to each element of list `x`



- E.g., in Python:

```
def square(x): return x*x
```

`map(square, [1, 2, 3, 4])` would return `[1, 4, 9, 16]`

- Parallel map implementation is trivial
  - What is the work? What is the depth?

Reduce

- `reduce(f, x[0…n-1])`
  - Repeatedly apply binary function `f` to pairs of items in `x`, replacing the pair of items with the result until only one item remains
  - One sequential Python implementation:

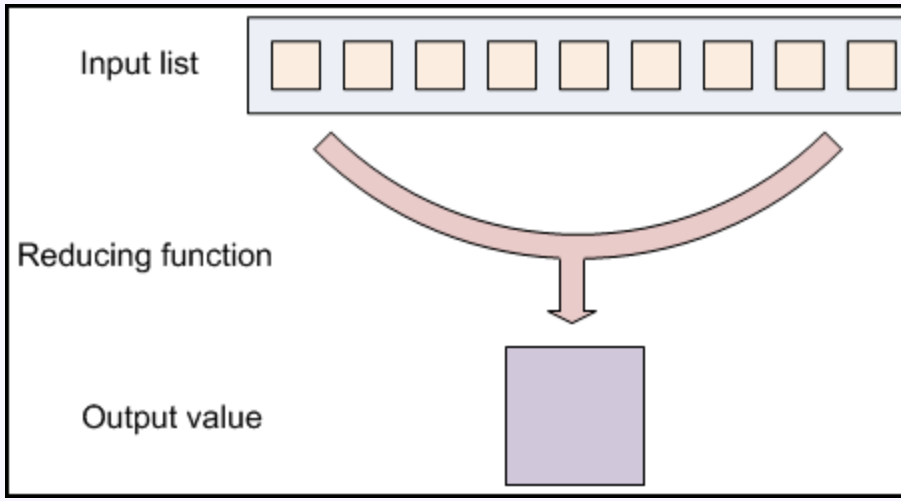
```
def reduce(f, x):
    if len(x) == 1: return x[0]
    return reduce(f, [f(x[0],x[1])] + x[2:])
```

  - e.g., in Python:

```
def add(x,y): return x+y
reduce(add, [1,2,3,4])
```

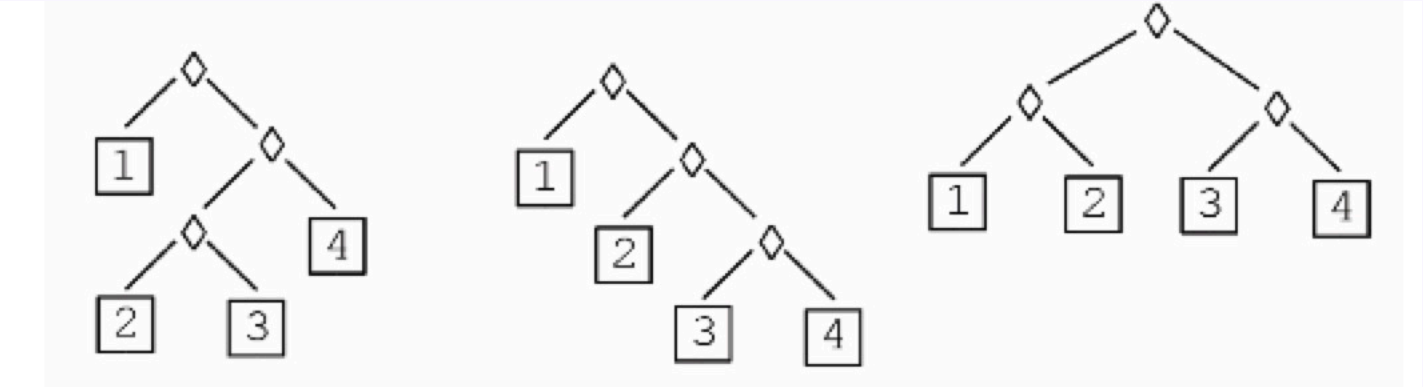
    would return 10 as

```
reduce(add, [1,2,3,4])
reduce(add, [3,3,4])
reduce(add, [6,4])
reduce(add, [10]) -> 10
```



Reduce with an associative binary function

- If the function `f` is associative, the order `f` is applied does not affect the result



1 + ((2+3) + 4) 1 + (2 + (3+4)) (1+2) + (3+4)

- Parallel reduce implementation is also easy
  - What is the work? What is the depth?

Distributed Map / Reduce

- The distributed map-reduce idea is just:

```
reduce(f2, map(f1, x))
```

- Key idea: a "data-centric" architecture
  - Send function `f1` directly to the data
    - Execute it concurrently
  - Then merge results with reduce
    - Also concurrently

Map and Reduce with keys (as told by Google)

- E.g., for each word on the Web, count the number of times that word occurs
  - For Map: `key1` is a document name, `value` is the contents of that document
  - For Reduce: `key2` is a word, `values` is a list of the number of counts of that word

```
Map(String key1, String value):
  for each word w in value:
    EmitIntermediate(w, "1");
```

```
Reduce(String key2, Iterator values):
  int result = 0;
  for each v in values:
    result += ParseInt(v);
  Emit(AsString(result));
```

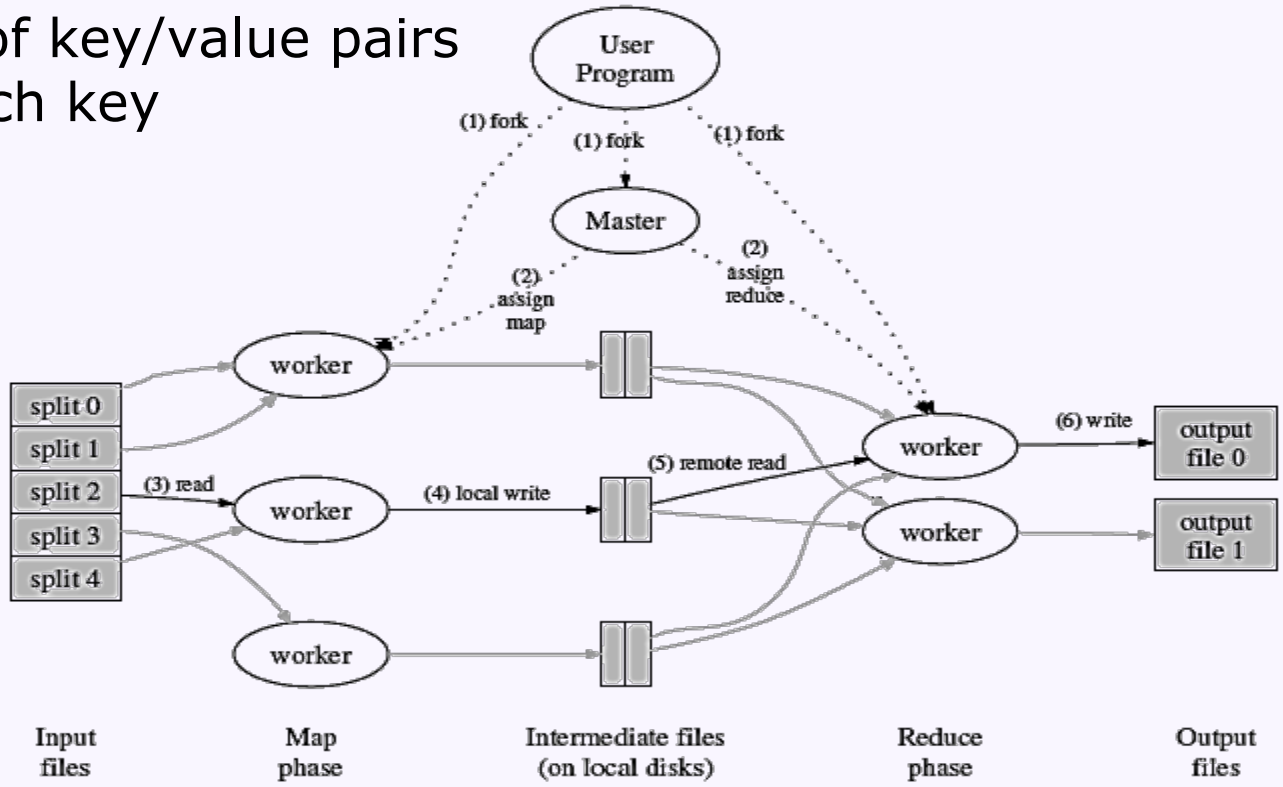
Map: (key1, v1) → (key2, v2)* Reduce: (key2, v2*) → v2*

MapReduce: (key1, v1)* → (key2, v2*)*

MapReduce: (docName, docText)* → (word, wordCount)*

Map and Reduce with keys (as told by Google)

- Master:
  - Assigns tasks to map and reduce workers
  - Pings workers to test for failures
- Reduce workers:
  - Remote read of key/value pairs
  - Reduce for each key



A map-reduce task for you

- Use map and reduce to generate an inverted index
  - E.g., given `(docName, docContents)` pairs for each document on the Web, build `(word, docNameList)` pairs for each word on the web, where `docNameList` is a list of all the document names containing that word
- Start by figuring out, for map and reduce: what are the keys and what are the values? I.e., what are the intermediate (key, value) pairs?
- Then describe pseudocode for map and reduce

Next time:

- Higher-level Java tools for concurrent programming