61A Lecture 34

Monday, December 2

Announcements

- Recursive art contest entries due Monday 12/2 @ 11:59pm
- Guerrilla section about logic programming on Monday 12/2 1pm-3:30pm in 273 Soda
- Homework 11 due Thursday 12/5 @ 11:59pm
- No video of lecture on Friday 12/6
  - Come to class and take the final survey
  - There will be a screencast of live lecture (as always)
  - Screencasts: http://www.youtube.com/view_play_list?p=-XXv-cvA_iCIEwJhyDVdyLMCiimv6Tup

Unix

Systems

Systems research enables the development of applications by defining and implementing abstractions:

- **Operating systems** provide a stable, consistent interface to unreliable, inconsistent hardware.
- **Networks** provide a simple, robust data transfer interface to constantly evolving communications infrastructure.
- **Databases** provide a declarative interface to software that stores and retrieves information efficiently.
- **Distributed systems** provide a unified interface to a cluster of multiple machines.

A unifying property of effective systems:

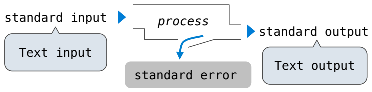
Hide *complexity*, but retain *flexibility*

The Unix Operating System

Essential features of the Unix operating system (and variants):

- **Portability:** The same operating system on different hardware.
- **Multi-Tasking:** Many processes run concurrently on a machine.
- **Plain Text:** Data is stored and shared in text format.
- **Modularity:** Small tools are composed flexibly via pipes.

"We should have some ways of coupling programs like [a] garden hose — screw in another segment when it becomes necessary to massage data in another way," Doug McIlroy in 1964.



The ***standard streams*** in a Unix-like operating system are similar to Python iterators.

(Demo)

```
ls *.py | cut -f 1 -d '.' | grep hw | cut -c 3- | sort -n
```

Python Programs in a Unix Environment

The built-in input function reads a line from *standard input*.

The built-in print function writes a line to *standard output*.

(Demo)

The values sys.stdin and sys.stdout also provide access to the Unix *standard streams* as files.

A Python file is an interface that supports iteration, read, and write methods.

Using these "files" takes advantage of the operating system *standard stream* abstraction.

(Demo)

MapReduce

Big Data Processing

MapReduce is a *framework* for batch processing of Big Data.

- **Framework:** A system used by programmers to build applications.
- **Batch processing:** All the data is available at the outset, and results aren't used until processing completes.
- **Big Data:** Used to describe data sets so large that they can reveal new facts about the world, usually from statistical analysis.

The MapReduce idea:

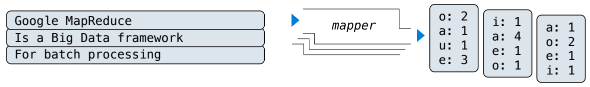
- Data sets are too big to be analyzed by one machine.
- Using multiple machines has the same complications, regardless of the application.
- Pure functions enable an abstraction barrier between data processing logic and coordinating a distributed application.

(Demo)

MapReduce Evaluation Model

Map phase: Apply a *mapper* function to inputs, emitting intermediate key-value pairs.

- The *mapper* takes an iterator over inputs, such as text lines.
- The *mapper* yields zero or more key-value pairs per input.



Google MapReduce
Is a Big Data framework
For batch processing

mapper

o: 2
a: 1
u: 1
e: 3

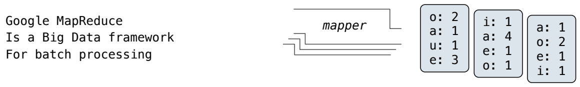
i: 1
a: 4
e: 1
o: 1

a: 1
o: 2
e: 1
i: 1

Reduce phase: For each intermediate key, apply a *reducer* function to accumulate all values associated with that key.

- The *reducer takes* an iterator over key-value pairs.
- All pairs with a given key are consecutive.
- The *reducer* yields 0 or more values, each associated with that intermediate key.

MapReduce Evaluation Model



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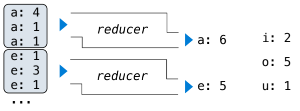


a: 4
a: 1
a: 1
e: 1
e: 3
e: 1
...

reducer

a: 6

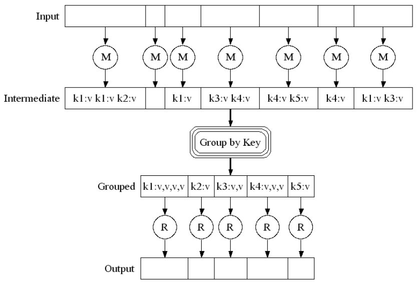
reducer

e: 5

i: 2
o: 5
u: 1

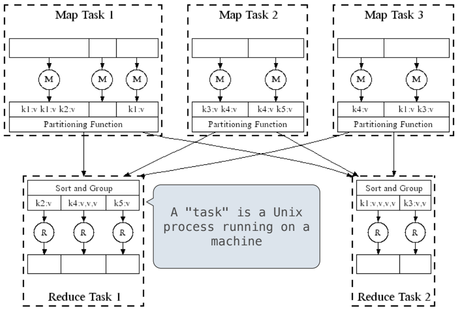
MapReduce Execution Model

Execution Model

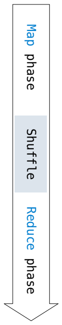


http://research.google.com/archive/mapreduce-osdi04-slides/index-auto-0007.html

Parallel Execution Implementation



A "task" is a Unix process running on a machine



http://research.google.com/archive/mapreduce-osdi04-slides/index-auto-0008.html

MapReduce Assumptions

Constraints on the *mapper* and *reducer*:

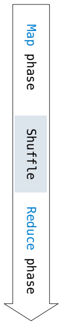
- The *mapper* must be equivalent to applying a deterministic pure function to each input independently.
- The *reducer* must be equivalent to applying a deterministic pure function to the sequence of values for each key.

Benefits of functional programming:

- When a program contains only pure functions, call expressions can be evaluated in any order, lazily, and in parallel.
- *Referential transparency*: a call expression can be replaced by its value (or *vis versa*) without changing the program.

In MapReduce, these functional programming ideas allow:

- Consistent results, however computation is partitioned.
- Re-computation and caching of results, as needed.



MapReduce Applications

Python Example of a MapReduce Application

The *mapper* and *reducer* are both self-contained Python programs.

- Read from *standard input* and write to *standard output*!

Mapper

```
#!/usr/bin/env python3

import sys
from mr import emit

def emit_vowels(line):
    for vowel in 'aeiou':
        count = line.count(vowel)
        if count > 0:
            emit(vowel, count)

for line in sys.stdin:
    emit_vowels(line)
```

Tell Unix: This is Python 3 code

The **emit** function outputs a key and value as a line of text to standard output

Mapper inputs are lines of text provided to standard input

Python Example of a MapReduce Application

The *mapper* and *reducer* are both self-contained Python programs.

- Read from *standard input* and write to *standard output*!

Reducer

```
#!/usr/bin/env python3

import sys
from mr import emit, values_by_key
```

Takes and returns iterators

Input: lines of text representing key-value pairs, grouped by key

Output: Iterator over (key, value_iterator) pairs that give all values for each key

```
for key, value_iterator in values_by_key(sys.stdin):
    emit(key, sum(value_iterator))
```

MapReduce Benefits

What Does the MapReduce Framework Provide

Fault tolerance: A machine or hard drive might crash.

- The MapReduce framework automatically re-runs failed tasks.

Speed: Some machine might be slow because it's overloaded.

- The framework can run multiple copies of a task and keep the result of the one that finishes first.

Network locality: Data transfer is expensive.

- The framework tries to schedule map tasks on the machines that hold the data to be processed.

Monitoring: Will my job finish before dinner?!?

- The framework provides a web-based interface describing jobs.

(Demo)