61A Lecture 36

Monday, April 27

Announcements

- Recursive Art Contest Entries due Monday 4/27 @ 11:59pm
  - Email your code & a screenshot of your art to cs61a-tae@imail.eecs.berkeley.edu (Albert)
- Homework 9 (4 pts) due Wednesday 4/29 @ 11:59pm
  - Homework Party Tuesday 5pm–6:30pm on Tuesday 4/28 in 2050 VLSB
  - Go to lab next week for help on the SQL homework! (There's also a lab.)
- Quiz 4 (SQL) released on Tuesday 4/28 is due Thursday 4/30 @ 11:59pm

Unix

Computer 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 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:

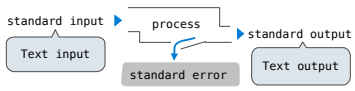
Hide complexity, but retain flexibility

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 hw* | grep -v html | cut -f 1 -d '.' | 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 **sys.stdin** and **sys.stdout** values provide access to the Unix standard streams as files

A Python file has an interface that supports iteration, **read**, and **write** methods

Using these "files" takes advantage of the operating system text processing 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 and comprehensive that they can reveal facts about a whole population, 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/analysis
- Pure functions enable an abstraction barrier between data processing logic and coordinating a distributed application

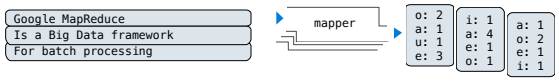
(Demo)

http://www.google.com/trends/explore

MapReduce Evaluation Model

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

- The mapper takes an iterable value containing inputs, such as lines of text
- The mapper yields zero or more key-value pairs for each input

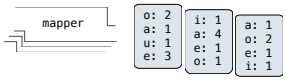


Reduce phase: For each intermediate key, apply a *reducer* function to accumulate all values associated with that key

- The reducer takes an iterable value containing intermediate key-value pairs
- All pairs with the same key appear consecutively
- The reducer yields zero or more values, each associated with that intermediate key

MapReduce Evaluation Model

Google MapReduce
Is a Big Data framework
For batch processing



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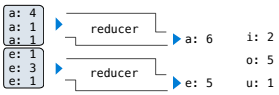
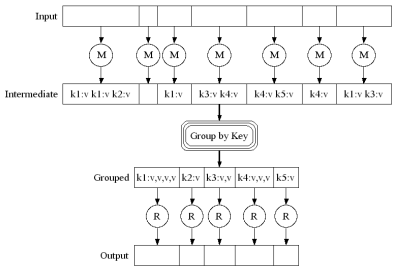


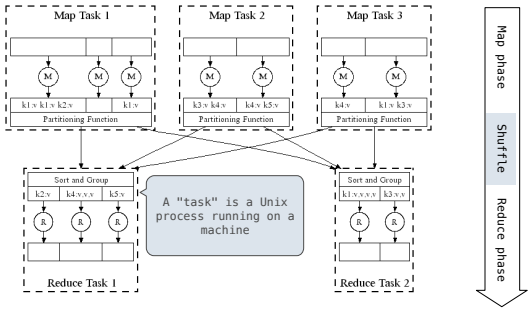
MapReduce Execution Model

Execution Model



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

Parallel Execution Implementation



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

- They read from standard input and write to standard output

Mapper

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

Tell Unix: This is Python 3 code

```
import sys
from mr import emit
```

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

```
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)
```

Mapper inputs are lines of text provided to standard input

(Demo)

Python Example of a MapReduce Application

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

- They read from standard input and write to standard output

Reducer

```
#!/usr/bin/env python3
import sys
from mr import emit, values_by_key

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

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

(Demo)

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)