61A Lecture 36

Announcements

Unix

Computer Systems

Systems research enables application development 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 complex 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:

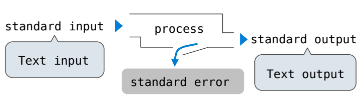
Hide complexity, but retain flexibility

Example: 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)

`cd .../assets/slides && ls *.pdf | cut -f 1 -d - | sort -r | uniq -c`

Python Programs in a Unix Environment

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

The **input** and **print** functions also read from standard input and write to standard output

(Demo)

Big Data

Big Data Examples

Facebook's daily logs: 60 Terabytes (60,000 Gigabytes)

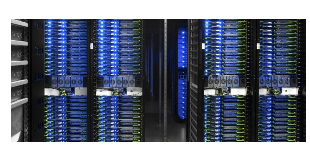
1,000 genomes project: 200 Terabytes

Google web index: 10+ Petabytes (10,000,000 Gigabytes)

Time to read 1 Terabyte from disk: 3 hours (100 Megabytes/second)

Typical hardware for big data applications:

- Consumer-grade hard disks and processors
- Independent computers are stored in racks
- Concerns: networking, heat, power, monitoring
- When using many computers, some will fail!



Facebook datacenter (2014)

Examples from Anthony Joseph

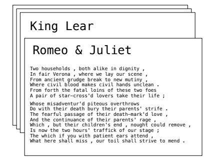
Apache Spark

Apache Spark

Apache Spark is a data processing system that provides a simple interface for large data

- A Resilient Distributed Dataset (RDD) is a collection of values or key-value pairs
- Supports common UNIX operations: **sort**, **distinct** (**uniq** in UNIX), **count**, **pipe**
- Supports common sequence operations: **map**, **filter**, **reduce**
- Supports common database operations: **join**, **union**, **intersection**

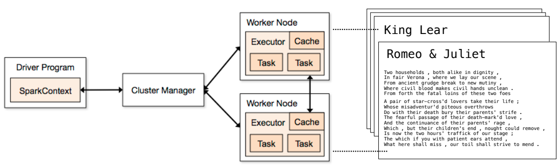
All of these operations can be performed on RDDs that are partitioned across machines



Apache Spark Execution Model

Processing is defined centrally but executed remotely

- A Resilient Distributed Dataset (RDD) is distributed in partitions to *worker nodes*
- A *driver program* defines transformations and actions on an RDD
- A *cluster manager* assigns tasks to individual *worker nodes* to carry them out
- Worker nodes perform computation & communicate values to each other
- Final results are communicated back to the driver program



Apache Spark Interface

The Last Words of Shakespeare (Demo)

A **SparkContext** gives access to the cluster manager

```
>>> sc
<pyspark.context.SparkContext ...>
```

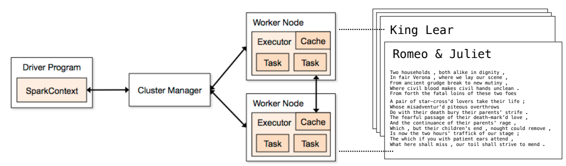
A RDD can be constructed from the lines of a text file

```
>>> x = sc.textFile('shakespeare.txt')
```

The **sortBy** transformation and **take** action are methods

```
>>> x.sortBy(lambda s: s, False).take(2)
['you shall ...', 'yet , a ...']
```

(Demo)



What Does Apache Spark Provide?

Fault tolerance: A machine or hard drive might crash

- The cluster manager automatically re-runs failed tasks

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

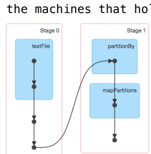
- The cluster manager can run multiple copies of a task and keep the result of the one that finishes first

Network locality: Data transfer is expensive

- The cluster manager tries to schedule computation on the machines that hold the data to be processed

Monitoring: Will my job finish before dinner?!?

- The cluster manager provides a web-based interface describing jobs



MapReduce

MapReduce Applications

An important early distributed processing system was MapReduce, developed at Google

Generic application structure that happened to capture many common data processing tasks

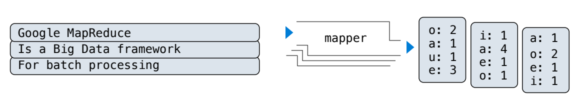
- Step 1: Each element in an input collection produces zero or more key-value pairs (map)
- Step 2: All key-value pairs that share a key are aggregated together (shuffle)
- Step 3: The values for a key are processed as a sequence (reduce)

Early applications: indexing web pages, training language models, & computing PageRank

MapReduce Evaluation Model

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

- The mapper yields zero or more key-value pairs for each input

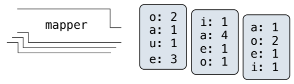


Reduce phase: For each intermediate key, apply a *reducer* function to accumulate all values associated with that key

- All key-value pairs with the same key are processed together
- 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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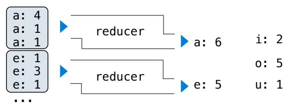

MapReduce Applications on Apache Spark

Key-value pairs are just two-element Python tuples

Call Expression	**Data**	**fn Input**	**fn Output**	**Result**
data.**flatMap**(fn)	Values	One value	Zero or more key-value pairs	All key-value pairs returned by calls to fn
data.**reduceByKey**(fn)	Key-value pairs	Two values	One value	One key-value pair for each unique key

(Demo)