MapReduce

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

What does that mean?

- **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**: A buzzword used to describe data sets so large that they reveal facts about the world via statistical analysis.

The MapReduce idea:

- Data sets are too big to be analyzed by one machine.
- When using multiple machines, systems issues abound.
- Pure functions enable an abstraction barrier between data processing logic and distributed system administration.

(Demo)
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 single-entity-level 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.

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

(Demo)
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 Evaluation Model

**Map phase:** Apply a *mapper* function to inputs, emitting a set of *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

```
| o: | 2 |
| a: | 1 |
| e: | 3 |
| i: | 1 |
| a: | 4 |
| e: | 1 |
| o: | 2 |
| 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

Google MapReduce
Is a Big Data framework
For batch processing

**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.
Above-the-Line: Execution model

Input

Intermediate

Intermediate

Group by Key

Grouped

Output

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

**Constraints** on the *mapper* and *reducer*:

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

```python
#!/usr/bin/env python3
import sys
from ucb import main
from mapreduce import emit

for line in sys.stdin:
    emit_vowels(line)

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

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

**Mapper**

Tell Unix: this is Python

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**

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

import sys
from ucb import main
from mapreduce import emit, group_values_by_key

Reducer

for key, value_iterator in group_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
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)