61A Lecture 34

Monday, December 2
Announcements
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• Recursive art contest entries due Monday 12/2 @ 11:59pm
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  • Screencasts: http://www.youtube.com/view_play_list?p=-XXv–cvA_iCIEwJhyDVdyLMCiimv6Tup
Unix
Systems
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A unifying property of effective systems:

Hide *complexity*, but retain *flexibility*
The Unix Operating System
Essential features of the Unix operating system (and variants):
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The *standard streams* in a Unix-like operating system are similar to Python iterators.

(Demo)

```bash
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*. 

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The values `sys.stdin` and `sys.stdout` also provide access to the Unix *standard streams* as files.
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(Demo)
MapReduce
Big Data Processing
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MapReduce is a *framework* for batch processing of Big Data.
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*Framework*: A system used by programmers to build applications.
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MapReduce Evaluation Model
**MapReduce Evaluation Model**

**Map phase:** Apply a *mapper* function to inputs, emitting *intermediate key-value pairs.*
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- The *mapper* takes an iterator over inputs, such as text lines.  
- The *mapper* yields zero or more *key-value pairs* per input.
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Google MapReduce
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mapper

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

```
mapper
```

<table>
<thead>
<tr>
<th>o</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>1</td>
</tr>
<tr>
<td>u</td>
<td>1</td>
</tr>
<tr>
<td>e</td>
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```
mapper
```

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

```
  i: 1
  a: 4
  e: 1
  o: 1
```
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<table>
<thead>
<tr>
<th>a: 1</th>
<th>e: 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>o: 2</td>
<td></td>
</tr>
<tr>
<td>i: 1</td>
<td></td>
</tr>
<tr>
<td>a: 4</td>
<td></td>
</tr>
<tr>
<td>e: 1</td>
<td></td>
</tr>
<tr>
<td>o: 1</td>
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**Reduce phase:** For each *intermediate key*, apply a *reducer* function to accumulate all values associated with that key.
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.

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mapper

o: 2
a: 1
u: 1
e: 3
h: 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.
MapReduce Evaluation Model

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

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a: 4
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...```
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\[
\begin{align*}
\text{mapper} & : \quad \text{a: 4, a: 1, a: 1, e: 1, e: 3, e: 1, ...} \\
\text{reducer} & : \quad \text{a: 6, i: 2} \\
\text{reducer} & : \quad \text{e: 5}
\end{align*}
\]
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MapReduce Execution Model
Execution Model

Parallel Execution Implementation

Map Task 1

Map Task 2

Map Task 3

Sort and Group

Reduce Task 1

Sort and Group

Reduce Task 2
A "task" is a Unix process running on a machine.

Parallel Execution Implementation

http://research.google.com/archive/mapreduce-osdi04-slides/index-auto-0008.html
A "task" is a Unix process running on a machine.
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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
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The mapper and reducer are both self-contained Python programs.
Python Example of a MapReduce Application

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

```python
def emit_vowels(line):
    for vowel in 'aeiou':
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from mr import emit

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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**

```python
#!/usr/bin/env python3
import sys
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Tell Unix: This is Python 3 code

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

#!/usr/bin/env python3

import sys
from mr import emit, values_by_key
```

```python
```
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Takes and returns iterators
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Reducer

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```

**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
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Reducer

```python
#!/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))
```

**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

Takes and returns iterators
MapReduce Benefits
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(Demo)