MapReduce for Large Scale Computing

Rationale for Map-Reduce

Map-reduce idea: An Example (part 1)

This example uses JavaScript.

```
// A trivial example:
   alert("I'd like some Spaghetti!");
   alert("I'd like some Chocolate Mousse!");
```

The above can be improved to the following code:

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// A trivial example:
    alert("I'd like some Spaghetti!");
    alert("I'd like some Chocolate Mousse!");
The above can be improved to the following code:
function SwedishChef( food )
    alert("I'd like some " + food + "!");
SwedishChef("Spaghetti");
SwedishChef("Chocolate Mousse");
```

Map-reduce idea: An Example (part 2)

```
alert("get the lobster");
PutInPot("lobster");
PutInPot("water");
alert("get the chicken");
BoomBoom("chicken");
BoomBoom("coconut");
```

The above can be improved to the following code using function pointers!

Map-reduce idea: An Example (part 2)

```
alert("get the lobster");
   PutInPot("lobster");
   PutInPot("water");
   alert("get the chicken");
   BoomBoom("chicken");
   BoomBoom("coconut");
The above can be improved to the following code using function pointers!
function Cook( i1, i2, f)
   alert("get the " + i1);
   f(i1):
   f(i2);
Cook( "lobster", "water", PutInPot );
Cook( "chicken", "coconut", BoomBoom );
```

Map-reduce idea: An Example (part 3)

Functions can be anonymous (like classes)

Map-reduce idea: An Example (part 4)

```
var a = [1,2,3];
for (i=0; i<a.length; i++) {
    a[i] = a[i] * a[i];
}
for (i=0; i<a.length; i++) {
    alert(a[i]);
}</pre>
```

Doing something to every element of an array can be done by a function using a function pointer for what needs to be done.

Map-reduce idea: An Example (part 4)

```
var a = [1,2,3];
for (i=0; i<a.length; i++) {
    a[i] = a[i] * a[i];
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    alert(a[i]);
}</pre>
```

Doing something to every element of an array can be done by a function using a function pointer for what needs to be done.

```
function map(fn, a)
{
    for (i = 0; i < a.length; i++) {
        a[i] = fn(a[i]);
    }
}
map( function(x){return x*x;}, a );
map( alert, a );</pre>
```

Map-reduce idea: An Example (part 5)

```
function sum(a)
   var s = 0;
   for (i = 0; i < a.length; i++)
       s += a[i];
   return s;
function join(a)
   var s = "";
   for (i = 0; i < a.length; i++)
       s += a[i];
   return s;
alert(sum([1,2,3]));
alert(join(["a","b","c"]));
```

Map-reduce idea: An Example (part 6)

```
function reduce(fn, a, init)
    var s = init;
    for (i = 0; i < a.length; i++)
        s = fn(s, a[i]);
    return s;
function sum(a)
    return reduce(function(a, b){ return a + b; }, a, 0);
function join(a)
    return reduce( function(a, b){ return a + b; }, a, "" );
```

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- Now as long as we can recast our problem as a map-reduce problem, it will automatically scale to thousands of processes!

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- How to deal with massive amounts of data that doesn't fit on one system?
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- ► How to deal with machines and components failing while the program is running?

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- Users specify a map function that processes a key/value pair to generate a set of intermediate key/value pairs, and a reduce function that merges all intermediate values associated with the same intermediate key.
- Allows programmers without any experience with parallel and distributed systems to easily utilize the resources of a large distributed system.





Introduced by Google. Used internally for all major computations on around 1m servers! Amazon leases servers to run map reduce computations (EC2 and S3 programs). Microsoft has developed Dryad (a super set of Map-Reduce).

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- ► The intermediate values are supplied to the user's reduce function via an iterator. This allows us to handle lists of values that are too large to fit in memory.

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- When the code runs, it leverages the MapReduce implementation to deal with distributed file systems, distributed computing, fault tolerance, reporting etc. For example, Hadoop provides a MapReduce framework.
- ► The output will be distributed in multiple files across the cluster, just as the input is. If the output is small, then it can be collected together, if not, we have to leave it distributed.

A MapReduce Pseudo-code Example

Consider the problem of counting the number of occurrences of each word in a large collection of documents.

```
//wordcount
map(String key, String value):
// key: document name
// value: document contents
1. for each word w in value:
2. emitIntermediate(w, "1");
reduce(String key, Iterable values):
// key: a word
// values: a list of counts
1. int result = 0;
2. for each v in values:
3. result += parseInt(v);

    emit(key, asString(result));
```

Word Count in MapReduce - example

```
f1: the and the cheetah
      f2: and and or mongoose bike
                                       Stored on a Distributed File System
      f3: the I cheetah or and and
         (the, 1) (and, 1) (the, 1) (cheetah, 1)
      (and, 1) (and, 1) (or, 1) (mongoose, 1) (bike, 1)
         (the, 1) (I, 1), (cheetah, 1) (or, 1) (and, 1) (and, 1)
kev = filename
value = line of text
                                  sort (secret, automatic)
                                                                                                  (and, 5)
                                                                 reduce(and, <1,1,1,1,1>).
          (and, 1) (and, 1) (and, 1) (and, 1)
                                                                                                  (cheetah,2)
          (bike, 1)
                                                                                                  (bike, 1)
                                                               → reduce ("cheetah", <1.1>)
          (cheetah, 1)(cheetah, 1)
                                                                                                 (1, 1)
          (1, 1)
                                                                                                  mongoose,
          (mongoose, 1)
                                                                                                  (or, 2)
          (or, 1)(or, 1)
                                                           →reduce ("the", <1,1,1>)
          (the, 1)(the, 1)(the, 1)
```

MapReduce Exercise



▶ Case Analysis or Capitalization Probability: In a collection of text documents, find the percentage capitalization for each letter of the alphabet. That is, (number of occurrences of a letter that are capitalized/ total number of occurrences for that letter) × 100.

```
file2: The THE THE file3: And AND AND result:
a: 3/4 * 100 = 75% t: 4/4 * 100 = 100% e: 1/4 * 100 = 25%
```

file1: The happy Fox

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- Distributed Grep: The map function emits a line if it matches a supplied pattern. The reduce function is an identity function that just copies the supplied intermediate data to the output.
- ► Count of URL Access Frequency: The map function processes logs of web page requests and outputs <URL, 1>. The reduce function adds together all values for the same URL and emits a <URL, total count> pair.
- ▶ Distributed Sort: The map function extracts the key from each record, and emits a <key, record> pair. The reduce function emits all pairs unchanged. This computation depends on the partitioning and ordering facilities that are provided in a MapReduce implementation.

Reverse Web-Link Graph:

- ► The map function outputs <target, source> pairs for each link to a target URL found in a page named source.
- ► The reduce function concatenates the list of all source URLs associated with a given target URL and emits the pair: <target, list(source)>

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```
//reverse web-link graph
 map(String key, String value):
 // key: document name
 // value: webpage contents of source page
 1. source = URL for source page
 2. for each link target found in value:
 3.
          emitIntermediate(target, source)
 reduce(String key, Iterable values):
 // key: target URL
 // values: a list of source URLs
 1. String urlList = ""
 2. for each v in values:
         urlList += v + ". "

    emit(key, asString(urlList));
```

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- How about computing a relevance of each document?

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- ► The reduce function accepts all pairs for a given word, sorts the corresponding document IDs and emits a <word, list(document ID)> pair.
- ▶ The set of all output pairs forms a simple inverted index.
- It is easy to augment this computation to keep track of word positions.
- How about computing a relevance of each document?
- How about also keeping track of the context (most relevant lines of text where it was found)

Inerted Index: MapReduce pseudo-code

```
//inverted index
map(String key, String value):
// key: document ID
// value: line by line of the document
1. id = key
2. for word in value:
       emitIntermediate(word, id)
reduce(String key, Iterable values):
// key: word
// values: a list of document IDs
1. list docList = initialize list
2. for each v in values:
3.
       docList += v
4. sort docList
   //it's possible to write data structures directly
   //instead of only strings
emit(key, docList)
```

MapReduce Exercise



► Find the number of citations for each patent in a patent reference data set. The format of the input is citing_patent, cited_patent

Describe a MapReduce algorithm to solve this problem.

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 Describe a MapReduce algorithm to solve this problem.

► Find the top *N* most frequently cited patents. The format of the input is

citing_patent, cited_patent

Describe a MapReduce algorithm to solve this problem.

Hint: This will take two passes.

References

- MapReduce: Simplified Data Processing on Large Clusters by Jeffrey Dean and Sanjay Ghemawat, Google Inc. Appeared in: OSDI'04: Sixth Symposium on Operating System Design and Implementation, San Francisco, CA, December, 2004.
- ► Can Your Programming Language Do This? by Joel Spolsky. http://www.joelonsoftware.com/items/2006/08/01.html