Pig, a high level data processing system on Hadoop

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Nov. 1, 2010

Agenda

- Recap on MapReduce
- Introduction to Pig
- View of Pig from outside
  - Pig Latin
- View of Pig from inside
  - Plan generation
- Future work

Recap on MapReduce

MapReduce

- Large scale data processing framework
- Map phase + Reduce phase
- Proposed at 2004 by Google
- Variance and extension in open source community (Hadoop, Pig, Hive, etc.)

MapReduce Programming Model

- Programmers think in a data-centric fashion
  - Apply transformations on data sets
- The MR framework handles the Hard Stuff
  - Fault tolerance
  - Distributed execution, scheduling, concurrency
  - Coordination
  - Network communication

MapReduce System Model

- Designed for batch-oriented computations over large data sets
  - Each operator runs to completion before producing any output
  - Operator output is written to stable storage
  - Map output to local disk, reduce output to HDFS
- Simple, elegant fault tolerance model: operator restart
  - Critical for large clusters

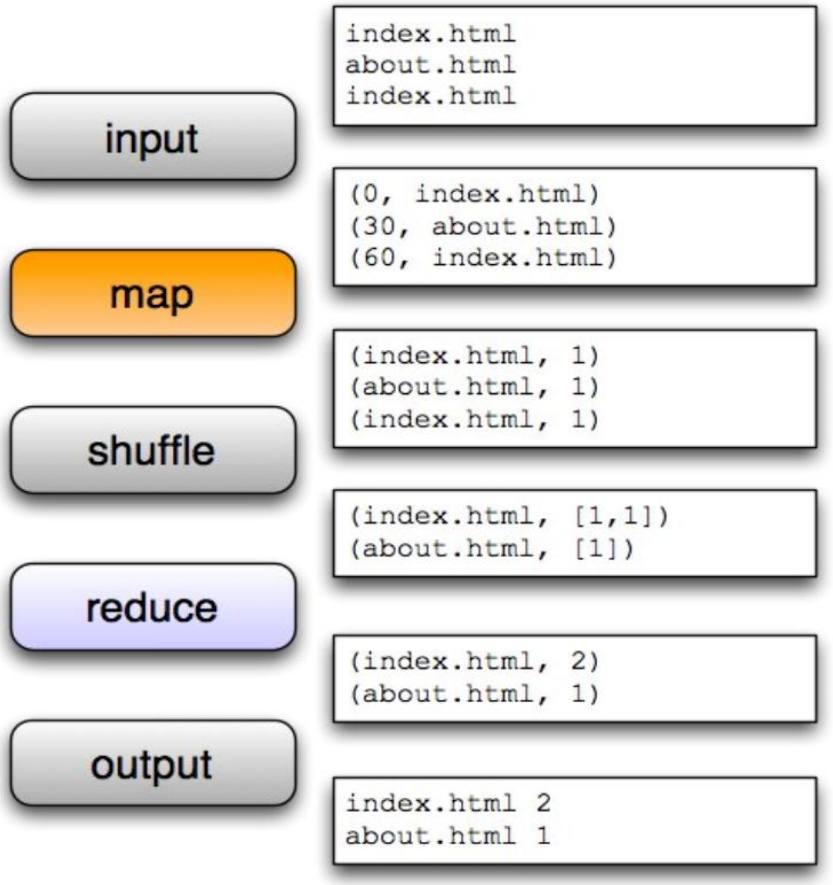
'Hello World'

- Word Count

- map(doc_id, text)
  - → list(word, count)
- reduce(word, list(count))
  - → list(sum_count)

  - Combiner is optional

'Hello World'


input
index.html
about.html
index.html
map
(0, index.html)
(30, about.html)
(60, index.html)
shuffle
(index.html, 1)
(about.html, 1)
(index.html, 1)
reduce
(index.html, [1,1])
(about.html, [1])
output
(index.html, 2)
(about.html, 1)
index.html 2
about.html 1

Hadoop

- Hadoop MapReduce Execution Engine
  - Single master node, many worker nodes
  - Client submits a job to master node
  - Master splits each job into tasks (map/reduce), and assigns tasks to worker nodes
- Hadoop Distributed File System (HDFS)
  - Single name node, many data nodes
  - Files stored as large, fixed-size (e.g. 64MB) blocks
  - HDFS typically holds map input and reduce output

Introduction to Pig

MapReduce not Good Enough?

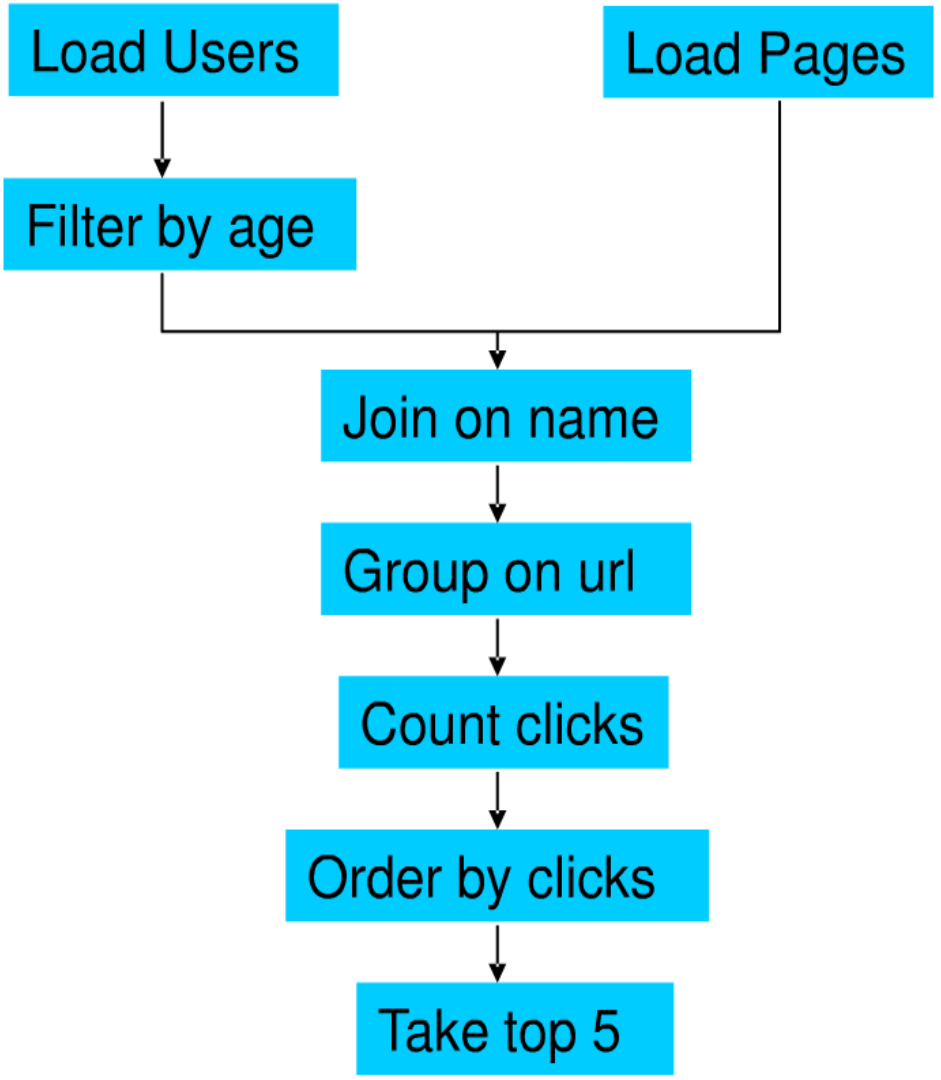
- Restrict programming model
  - Only two phases
  - Job chain for long data flow
- Put the logic at the right phase
  - Programmers are responsible for this
- Too many lines of code even for simple logic
  - How many lines do you have for word count?

Pig to Rescure

- High level dataflow language (Pig Latin)
  - Much simpler than Java
  - Simplify the data processing
- Put the operations at the apropriate phases
- Chains multiple MR jobs

Motivation by Example

- Suppose we have user data in one file, website data in another file.
- We need to find the top 5 most visited pages by users aged 18-25

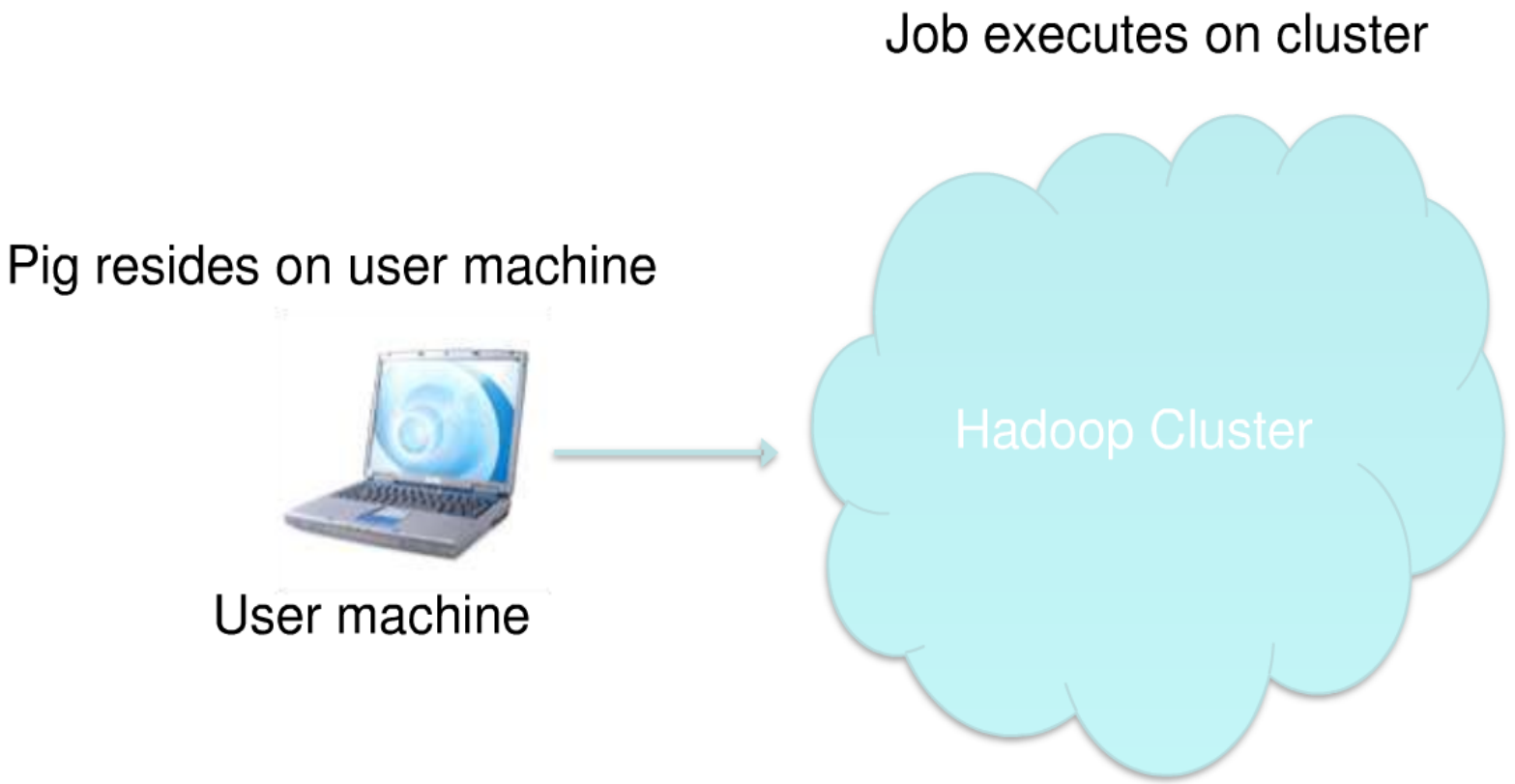


In MapReduce

In Pig Latin

```
Users = load 'users' as (name, age);
Fltrd = filter Users by
        age >= 18 and age <= 25;
Pages = load 'pages' as (user, url);
Jnd = join Fltrd by name, Pages by user;
Grpd = group Jnd by url;
Smmd = foreach Grpd generate group,
COUNT(Jnd) as clicks;
Srtd = order Smmd by clicks desc;
Top5 = limit Srtd 5;
store Top5 into 'top5sites';
```

Pig runs over Hadoop



No need to install anything extra on your Hadoop cluster.

How Pig is used in Industry

- At Yahoo, 70% MapReduce jobs are written in Pig
- Used to
  - Process web log
  - Build user behavior models
  - Process images
  - Data mining
- Also used by Twitter, Linkin, Ebay, AOL, etc.

View of Pig from outside

MapReduce vs. Pig

- MaxTemperature

Year	Temperature	Air Quality	…
1998	87	2	…
1983	93	4	..
2008	90	3	…
2001	89	5	…
1965	97	4	…

Table1

```
SELECT Year, MAX(Temperature)
FROM  Table1
WHERE AirQuality = 0|1|4|5|9
GROUPBY Year
```

In MapReduce

```java
// cc MaxTemperatureMapper Mapper for maximum temperature example
// vv MaxTemperatureMapper
import java.io.IOException;

import org.apache.hadoop.io.IntWritable;
import org.apache.hadoop.io.LongWritable;
import org.apache.hadoop.io.Text;
import org.apache.hadoop.mapred.MapReduceBase;
import org.apache.hadoop.mapred.Mapper;
import org.apache.hadoop.mapred.OutputCollector;
import org.apache.hadoop.mapred.Reporter;

public class MaxTemperatureMapper extends MapReduceBase
  implements Mapper<LongWritable, Text, Text, IntWritable> {

  private static final int MISSING = 9999;

  public void map(LongWritable key, Text value,
      OutputCollector<Text, IntWritable> output, Repo
      throws IOException {

    String line = value.toString();
    String year = line.substring(15, 19);
    int airTemperature;
    if (line.charAt(87) == '+') { // parseInt doesn't
      airTemperature = Integer.parseInt(line.substrin
    } else {
      airTemperature = Integer.parseInt(line.substrin
    }
    String quality = line.substring(92, 93);
    if (airTemperature != MISSING && quality.matches(
      output.collect(new Text(year), new IntWritable(
    }
  }
}
// ^^ MaxTemperatureMapper
```

```java
// cc MaxTemperatureReducer Reducer for maximum temperature example
// cc MaxTemperatureReducer2 Reducer for maximum temperature example
// vv MaxTemperatureReducer
import java.io.IOException;
import java.util.Iterator;

import org.apache.hadoop.io.IntWritable;
import org.apache.hadoop.io.Text;
import org.apache.hadoop.mapred.MapReduceBase;
import org.apache.hadoop.mapred.OutputCollector;
import org.apache.hadoop.mapred.Reducer;
import org.apache.hadoop.mapred.Reporter;

// vv MaxTemperatureReducer2
public class MaxTemperatureReducer extends Ma
  implements Reducer<Text, IntWritable, Text,

  public void reduce(Text key, Iterator<IntWr
      OutputCollector<Text, IntWritable> outp
      throws IOException {

    int maxValue = Integer.MIN_VALUE;
    while (values.hasNext()) {
      maxValue = Math.max(maxValue, values.ne
    }
    output.collect(key, new IntWritable(maxVa
  }
}
// ^^ MaxTemperatureReducer2
// ^^ MaxTemperatureReducer
```

```java
// cc MaxTemperature Application to find the maximum temperature in the weather dataset
// vv MaxTemperature
import java.io.IOException;

import org.apache.hadoop.fs.Path;
import org.apache.hadoop.io.IntWritable;
import org.apache.hadoop.io.Text;
import org.apache.hadoop.mapred.FileInputFormat;
import org.apache.hadoop.mapred.FileOutputFormat;
import org.apache.hadoop.mapred.JobClient;
import org.apache.hadoop.mapred.JobConf;

public class MaxTemperature {

  public static void main(String[] args) throws IOException {
    if (args.length != 2) {
      System.err.println("Usage: MaxTemperature <input path> <output path>");
      System.exit(-1);
    }

    JobConf conf = new JobConf(MaxTemperature.class);
    conf.setJobName("Max temperature");

    FileInputFormat.addInputPath(conf, new Path(args[0]));
    FileOutputFormat.setOutputPath(conf, new Path(args[1]));

    conf.setMapperClass(MaxTemperatureMapper.class);
    conf.setReducerClass(MaxTemperatureReducer.class);

    conf.setOutputKeyClass(Text.class);
    conf.setOutputValueClass(IntWritable.class);

    JobClient.runJob(conf);
  }
}
// ^^ MaxTemperature
```

In Pig

```
-- max_temp.pig: Finds the maximum temperature by year
records = LOAD 'input/ncdc/micro-tab/sample.txt'
  AS (year:chararray, temperature:int, quality:int);
filtered_records = FILTER records BY temperature != 9999 AND
  (quality == 0 OR quality == 1 OR quality == 4 OR quality == 5 OR quality == 9);
grouped_records = GROUP filtered_records BY year;
max_temp = FOREACH grouped_records GENERATE group,
  MAX(filtered_records.temperature);
DUMP max_temp;
```

Wait a mimute

- How to map the data to records
  - By default, one line → one record
  - User can customize the loading process
- How to identify attributes and map them to schema
  - Delimitor to separate different attributes
  - By default, delimitor is tab. Customizable.

MapReduce vs. Pig cont.

- Join in MapReduce
  - Various algorithms. None of them are easy to implement in MapReduce
  - Multi-way join more complicated
  - Hard to integrate into SPJA workflow

MapReduce vs. Pig cont.

- Join in Pig
  - Various algorithms already available.
  - Some of them are generic to support multi-way join
  - No need to consider integration into SPJA workflow. Pig does that for you!

```
A = LOAD 'input/join/A';
B = LOAD 'input/join/B';
C = JOIN A BY $0, B BY $1;
DUMP C;
```

Pig Latin

- Data flow language
  - User specify a sequence of operations to process data
  - More control on the process, compared with declarative language
- Various data types supports
- Schema supports
- User defined functions supports

Statement

- A statement represents an operation, or a stage in the data flow.
- Usually a variable is used to represent the result of the statement
- Not limited to data processing operations, but also contains filesystem operations

Schema

- User can optionally define the schema of the input data
- Onec the schema of the source data is given, all the schema of the intermediate relation will be induced by Pig

Schema cont.

- Why schema?
  - Scripts are more readable (by alias)
  - Help system validate the input
- Similar to Database?
  - Yes. But schema here is optional
  - Schema is not fixed for a particular dataset, but changable

Schema cont.

- Schema 1

```
A = LOAD 'input/A' as (name:chararray, age:int);
B = FILTER A BY age != 20;
```

- Schema 2

```
A = LOAD 'input/A' as (name:chararray, age:chararray);
B = FILTER A BY age != '20';
```

- No Schema

```
A = LOAD 'input/A' ;
B = FILTER A BY A.$1 != '20';
```

Date Types

- Every attribute can always interpreted as bytearray, without further type definition
- Simple data types
  - For each attribute
  - Defined by user in the schema
  - Int, double, chararray ...
- Complex data types
  - Usually contructed by relational operations
  - Tuple, bag, map

Date Types cont.

- Type casting
  - Pig will try to cast data types when meets type inconsistency.
  - Warning will be thrown if casting fails. Process still goes on
- Validation
  - Null will replace the inconvertable data type in type casting
  - User can tell a corrupted record by detecting whether a particular attribute is null

Date Types cont.

```
1950    0   1
1950    22  1
1950    e   1
1949    111 1
1949    78  1
```

```
grunt> records = LOAD 'input/ncdc/micro-tab/sample_corrupt.txt'
>>   AS (year:chararray, temperature:int, quality:int);
grunt> DUMP records;
(1950,0,1)
(1950,22,1)
(1950,,1)
(1949,111,1)
(1949,78,1)
```

```
grunt> corrupt_records = FILTER records BY temperature is null;
grunt> DUMP corrupt_records;
(1950,,1)
```

Operators

- Relational Operators
  - Represent an operation that will be added to the logical plan
  - LOAD, STORE, FILTER, JOIN, FOREACH...GENERATE

```
grunt> DUMP A;
(2,Tie)
(4,Coat)
(3,Hat)
(1,Scarf)
grunt> DUMP B;
(Joe,2)
(Hank,4)
(Ali,0)
(Eve,3)
(Hank,2)
```

```
grunt> C = JOIN A BY $0, B BY $1;
grunt> DUMP C;
(2,Tie,Joe,2)
(2,Tie,Hank,2)
(3,Hat,Eve,3)
(4,Coat,Hank,4)
```

Operators

- Diagnostic Operators
  - Show the status/metadata of the relations
  - Used for debugging
  - Will not be integrated into execution plan
  - DESCRIBE, EXPLAIN, ILLUSTRATE.

```
grunt> records = LOAD 'input/ncdc/micro-tab/sample.txt'
>>   AS (year, temperature:int, quality:int);
grunt> DESCRIBE records;
records: {year: bytearray,temperature: int,quality: int}
```

Functions

- Eval Functions
  - Record transformation
- Filter Functions
  - Test whether a record satisfy particular predicate
- Comparison Functions
  - Impose ordering between two records. Used by ORDER operation
- Load Functions
  - Specify how to load data into relations
- Store Functions
  - Specify how to store relations to external storage

Functions

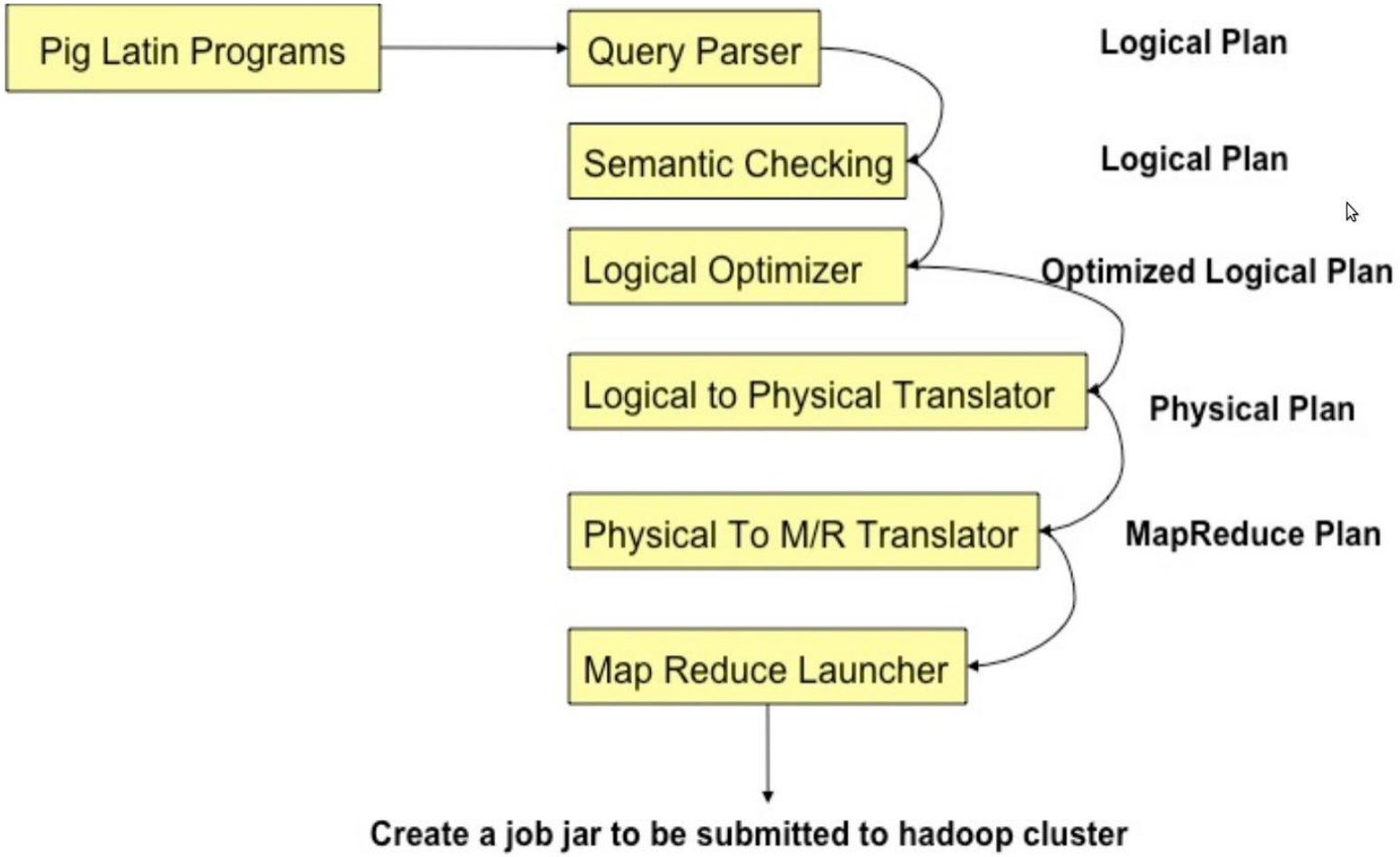
- Built in Functions
  - Hard-coded routines offered by Pig.
- User Defined Function (UDF)
  - Supports customized functionalities
  - Piggy Bank, a warehouse for UDFs.
  - Re-think about Word Count in Pig

View of Pig from inside

Pig Execution Modes

- Local mode
  - Launch single JVM
  - Access local file system
  - No MR job running
- Hadoop mode
  - Execute a sequence of MR jobs
  - Pig interacts with Hadoop master node

Compilation

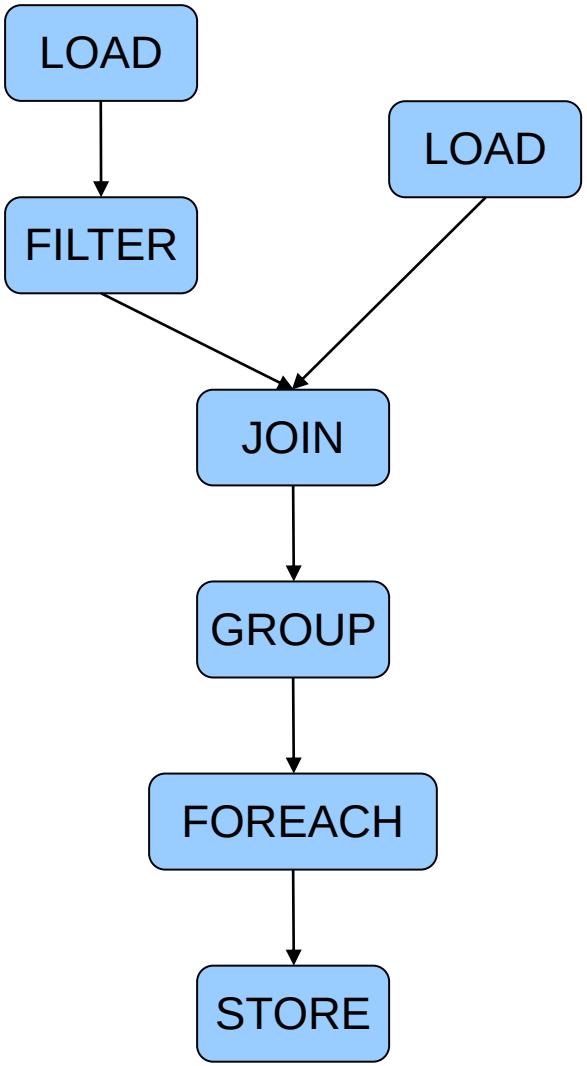


Parsing

- Type checking with schema
- References verification
- Logic plan generating
  - One-to-one fashion
  - Independent of execution platform
  - Limited optimization
  - No execution until DUMP or STORE

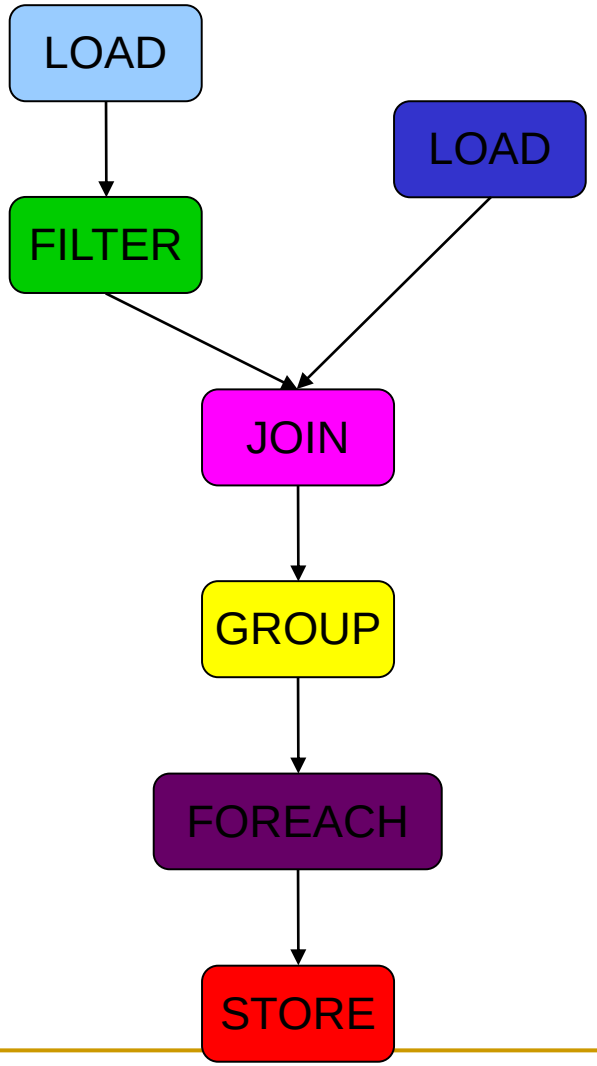
Logical Plan

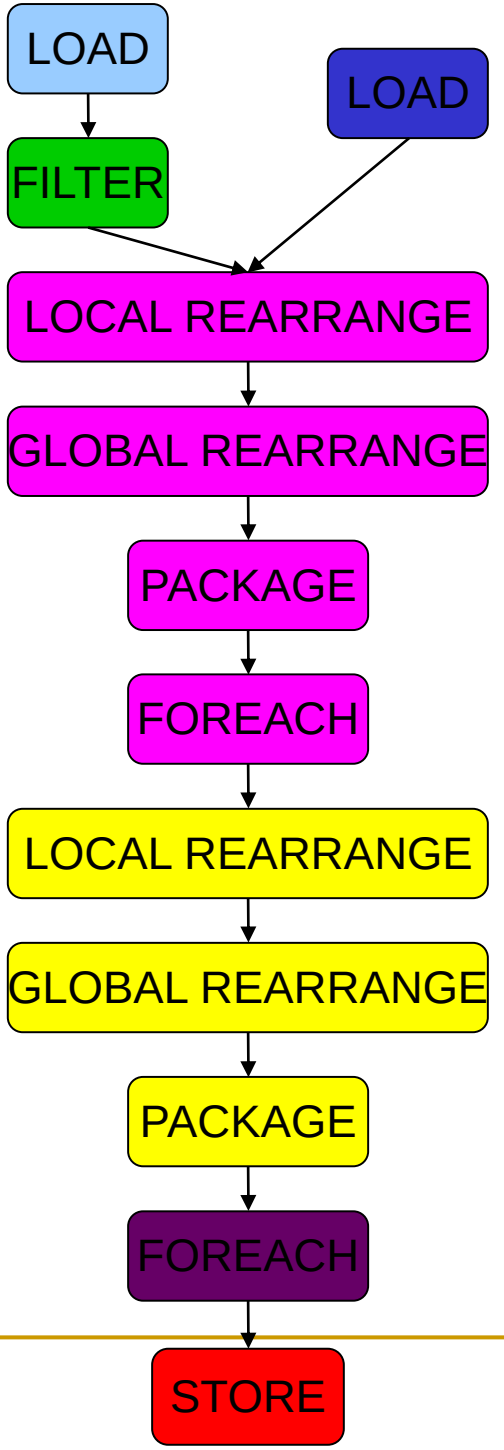
```
A=LOAD 'file1' AS (x, y, z);

B=LOAD 'file2' AS (t, u, v);

C=FILTER A by y > 0;

D=JOIN C BY x, B BY u;

E=GROUP D BY z;

F=FOREACH E GENERATE
      group, COUNT(D);

STORE F INTO 'output';
```



Physical Plan

- 1:1 correspondence with most logical operators
- Except for:
  - DISTINCT
  - (CO)GROUP
  - JOIN
  - ORDER


LOAD
LOAD
FILTER
JOIN
GROUP
FOREACH
STORE

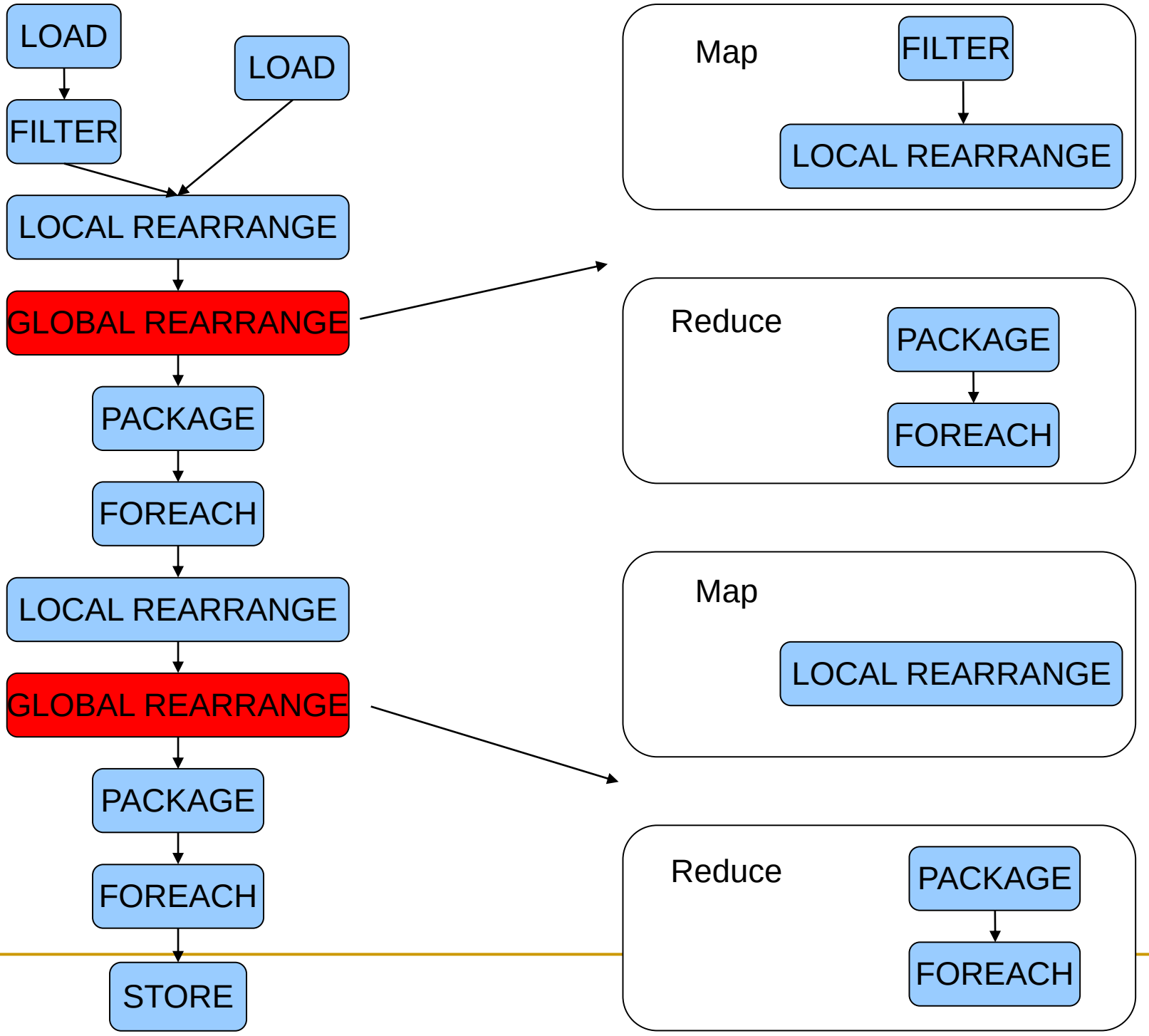

LOAD
LOAD
FILTER
LOCAL REARRANGE
GLOBAL REARRANGE
PACKAGE
FOREACH
LOCAL REARRANGE
GLOBAL REARRANGE
PACKAGE
FOREACH
STORE

Physical Oprimizations

- Always use combiner for pre-aggregation
- Insert SPLIT to re-use intermediate result
- Early projection

MapReduce Plan

- Determine MapReduce boundaries
  - GLOBAL REARRANGE
  - STORE/LOAD
- Some operations are done by MapReduce framework
- Coalesce other operators into Map & Reduce stages
- Generate job jar file

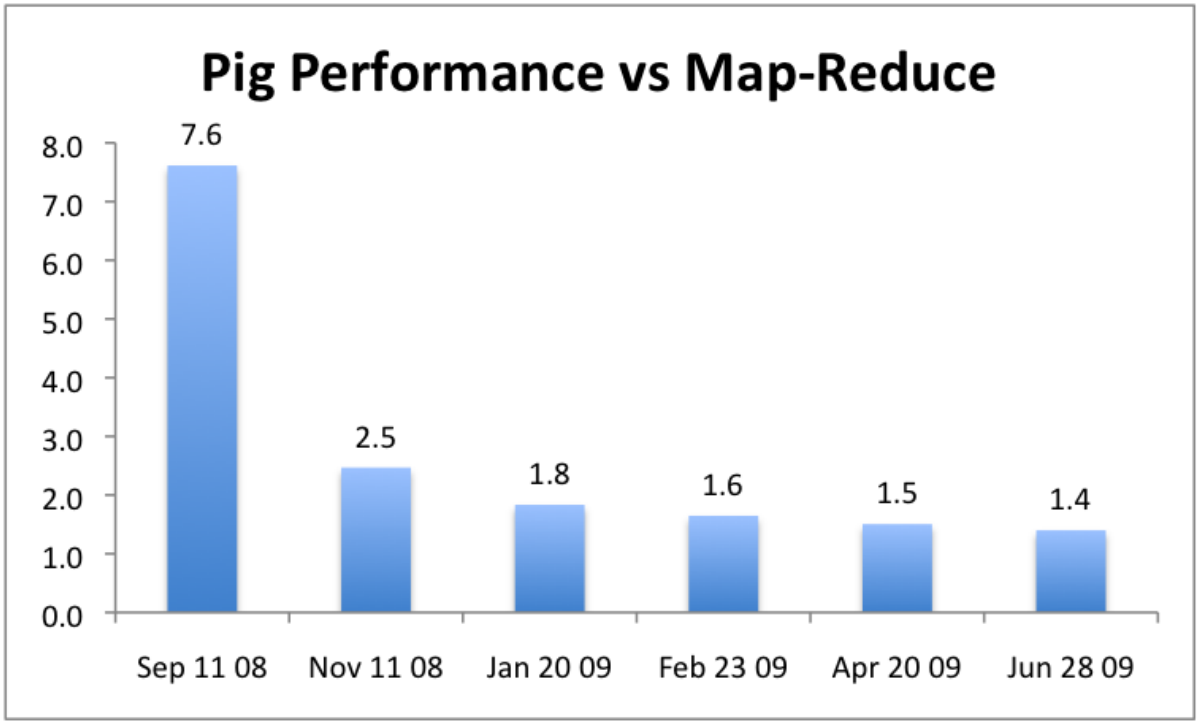

LOAD
LOAD
FILTER
LOCAL REARRANGE
GLOBAL REARRANGE
PACKAGE
FOREACH
LOCAL REARRANGE
GLOBAL REARRANGE
PACKAGE
FOREACH
STORE
Map
FILTER
LOCAL REARRANGE
Reduce
PACKAGE
FOREACH
Map
LOCAL REARRANGE
Reduce
PACKAGE
FOREACH

Execution in Hadoop Mode

- The MR jobs depending on nothing in the MR plan will be submitted for execution
- MR jobs will be removed from MR plan after completion
  - Depending jobs are now available for execution
- Currently, no supports for inter-job fault-tolerance

Performance and future improvement

Pig Performance



Images from http://wiki.apache.org/pig/PigTalksPapers

Future Improvements

- Query optimization
  - Currently rule-based optimizer for plan rearrangement and join selection
  - Cost-based in the future
- Non-Java UDFs
- Grouping and joining on pre-partitioned/sorted data
  - Avoid data shuffling for grouping and joining
  - Building metadata facilities to keep track of data layout
- Skew handling
  - For load balancing

- Get more information at Pig website
- You can touch the source code to implement something new in Pig
- Also take a look at Hive, a similar system from Facebook

References

- Some of the content come from the following presentations:
  - Introduction to data processing using Hadoop and Pig, by Ricardo Varela
  - Pig, Making Hadoop Easy, by Alan F. Gates
  - Large-scale social media analysis with Hadoop, by Jake Hofman
  - Getting Started on Hadoop, by Paco Nathan
  - MapReduce Online, by Tyson Condie and Neil Conway