Extensions of Map Reduce
Pig and Hive

Need for High-Level Languages

- Hadoop is great for large-data processing!
  - But writing Java programs for everything is verbose and slow
  - Data scientists don't want to write Java
- Solution: develop higher-level data processing languages
  - Hive: HQL is like SQL
  - Pig: Pig Latin is a bit like Perl

Hive and Pig

- Hive: data warehousing application in Hadoop
  - Query language is HQL, variant of SQL
  - Tables stored on HDFS with different encodings
  - Developed by Facebook, now open source
- Pig: large-scale data processing system
  - Scripts are written in Pig Latin, a dataflow language
  - Programmer focuses on data transformations
  - Developed by Yahoo!, now open source
- Common idea:
  - Provide higher-level language to facilitate large-data processing
  - Higher-level language “compiles down” to Hadoop jobs

Apache Pig

Based on slides from Adam Shook

What Is Pig?

- Developed by Yahoo! and a top level Apache project
- Immediately makes data on a cluster available to non-Java programmers via Pig Latin – a dataflow language
- Interprets Pig Latin and generates MapReduce jobs that run on the cluster
- Enables easy data summarization, ad-hoc reporting and querying, and analysis of large volumes of data
- Pig interpreter runs on a client machine – no administrative overhead required

Why Pig?

- Map reduce very low level!
- Need to write a lot of code and it is not interactive.
- Pig/Latin is introduced to address this

Pig Terms

- All data in Pig one of four types:
  - An Atom is a simple data value - stored as a string but can be used as either a string or a number
  - A Tuple is a data record consisting of a sequence of "fields"
    - Each field is a piece of data of any type (atom, tuple or bag)
  - A Bag is a set of tuples (also referred to as a ‘Relation’)
    - The concept of a “kind of a” table
  - A Map is a map from keys that are string literals to values that can be any data type
    - The concept of a hash map

Pig Capabilities

- Support for
  - Filtering
  - Grouping
  - Joins
  - Aggregation
- Extensibility
  - Support for User Defined Functions (UDF's)
- Leverages the same massive parallelism as native MapReduce

Pig Basics

- Pig is a client application
  - No cluster software is required
- Interprets Pig Latin scripts to MapReduce jobs
  - Parses Pig Latin scripts
  - Performs optimization
  - Creates execution plan
- Submits MapReduce jobs to the cluster

Execution Modes

- Pig has two execution modes
  - Local Mode - all files are installed and run using your local host and file system
  - MapReduce Mode - all files are installed and run on a Hadoop cluster and HDFS installation
- Interactive
  - By using the Grunt shell by invoking Pig on the command line

```
$ pig
grunt>
```

- Batch
  - Run Pig in batch mode using Pig Scripts and the "pig" command

```
$ pig –f id.pig –p <param>=<value> ...
```

Pig Latin

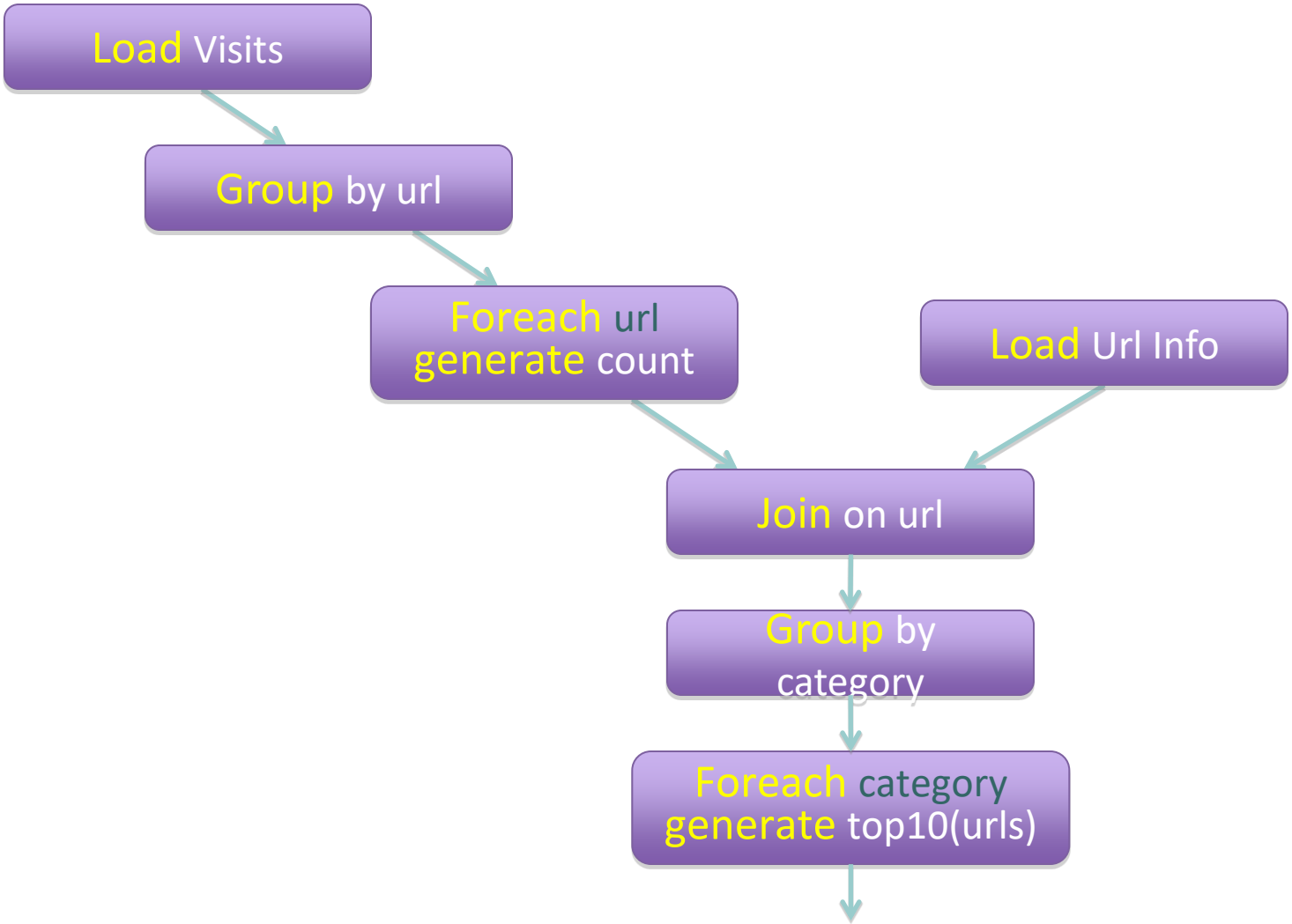
- Pig Latin scripts are generally organized as follows
  - A LOAD statement reads data
  - A series of “transformation” statements process the data
  - A STORE statement writes the output to the filesystem
    - A DUMP statement displays output on the screen
- Logical vs. physical plans:
  - All statements are stored and validated as a logical plan
  - Once a STORE or DUMP statement is found the logical plan is executed

Pig Script

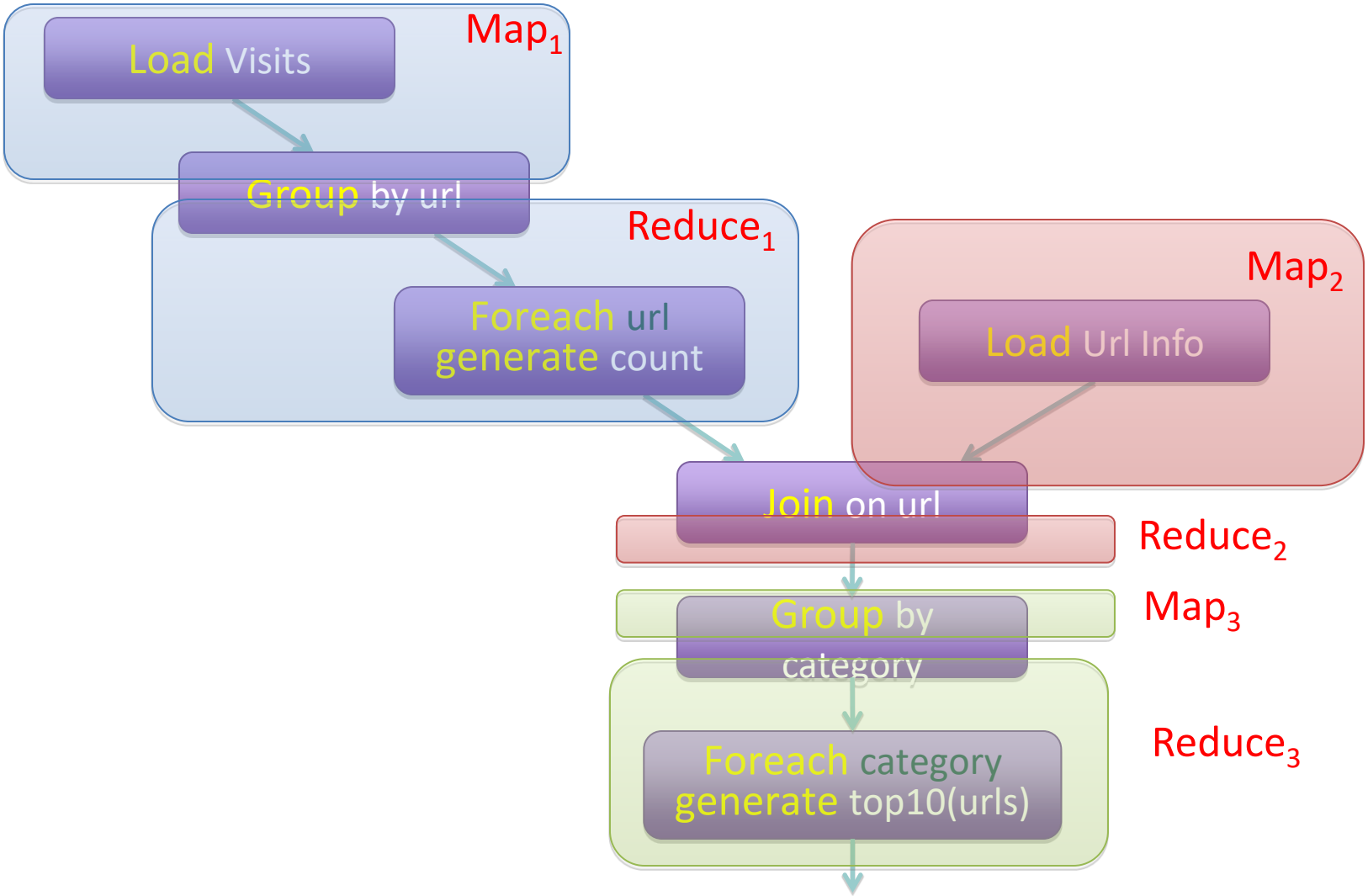
```
visits = load ‘/data/visits’ as (user, url, time);
gVisits = group visits by url;
visitCounts = foreach gVisits generate url, count(visits);
urlInfo = load ‘/data/urlInfo’ as (url, category, pRank);
visitCounts = join visitCounts by url, urlInfo by url;
gCategories = group visitCounts by category;
topUrls = foreach gCategories generate top(visitCounts,10);

store topUrls into ‘/data/topUrls’;
```

Pig Query Plan



Pig Script in Hadoop



Basic “grunt” Shell Commands

- Help is available

```
$ pig -h
```

- Pig supports HDFS commands

```
grunt> pwd
```

  – put, get, cp, ls, mkdir, rm, mv, etc.

About Pig Scripts

- Pig Latin statements grouped together in a file
- Can be run from the command line or the shell
- Support parameter passing
- Comments are supported
  - Inline comments '--'
  - Block comments /* */

Simple Data Types

Type	Description
int	4-byte integer
long	8-byte integer
float	4-byte (single precision) floating point
double	8-byte (double precision) floating point
bytearray	Array of bytes; blob
chararray	String (“hello world”)
boolean	True/False (case insensitive)
datetime	A date and time
biginteger	Java BigInteger
bigdecimal	Java BigDecimal

Complex Data Types

Type	Description
Tuple	Ordered set of fields (a “row / record”)
Bag	Collection of tuples (a “resultset / table”)
Map	A set of key-value pairs Keys must be of type chararray

Pig Data Formats

- BinStorage
  - Loads and stores data in machine-readable (binary) format
- PigStorage
  - Loads and stores data as structured, field delimited text files
- TextLoader
  - Loads unstructured data in UTF-8 format
- PigDump
  - Stores data in UTF-8 format
- YourOwnFormat!
  - via UDFs

Loading Data Into Pig

- Loads data from an HDFS file

```
var = LOAD 'employees.txt';
var = LOAD 'employees.txt' AS (id, name,
  salary);
var = LOAD 'employees.txt' using PigStorage()
        AS (id, name, salary);
```

- Each LOAD statement defines a new bag
  - Each bag can have multiple elements (atoms)
  - Each element can be referenced by name or position ($*n*)
- A bag is immutable
- A bag can be aliased and referenced later

Input And Output

- STORE
  - Writes output to an HDFS file in a specified directory

    ```
    grunt> STORE processed INTO 'processed_txt';
    ```

    - Fails if directory exists
    - Writes output files, part-[m|r]-xxxxx, to the directory
  - PigStorage can be used to specify a field delimiter
- DUMP
  - Write output to screen

    ```
    grunt> DUMP processed;
    ```

Relational Operators

- FOREACH
  - Applies expressions to every record in a bag
- FILTER
  - Filters by expression
- GROUP
  - Collect records with the same key
- ORDER BY
  - Sorting
- DISTINCT
  - Removes duplicates

FOREACH . . .GENERATE

- Use the FOREACH …GENERATE operator to work with rows of data, call functions, etc.
- Basic syntax:

```
alias2 = FOREACH alias1 GENERATE expression;
```

- Example:

```
DUMP alias1;
(1,2,3) (4,2,1) (8,3,4) (4,3,3) (7,2,5) (8,4,3)
alias2 = FOREACH alias1 GENERATE col1, col2;
DUMP alias2;
(1,2) (4,2) (8,3) (4,3) (7,2) (8,4)
```

FILTER. . .BY

- Use the FILTER operator to restrict tuples or rows of data
- Basic syntax:

```
alias2 = FILTER alias1 BY expression;
```

- Example:

```
DUMP alias1;
(1,2,3) (4,2,1) (8,3,4) (4,3,3) (7,2,5) (8,4,3)
alias2 = FILTER alias1 BY (col1 == 8) OR (NOT
   (col2+col3 > col1));
DUMP alias2;
(4,2,1) (8,3,4) (7,2,5) (8,4,3)
```

GROUP. . .ALL

- Use the GROUP…ALL operator to group data
  - Use GROUP when only one relation is involved
  - Use COGROUP with multiple relations are involved
- Basic syntax:

```
alias2 = GROUP alias1 ALL;
```

- Example:

```
DUMP alias1;
(John,18,4.0F) (Mary,19,3.8F) (Bill,20,3.9F)
   (Joe,18,3.8F)
alias2 = GROUP alias1 BY col2;
DUMP alias2;
(18,{(John,18,4.0F),(Joe,18,3.8F)})
(19,{(Mary,19,3.8F)})
(20,{(Bill,20,3.9F)})
```

Pig: COGROUPing

A = LOAD 'myfile.txt' AS (f1: int, f2: int, f3: int);

A:
(1, 2, 3)
(4, 2, 1)
(8, 3, 4)
(4, 3, 3)
(7, 2, 5)
(8, 4, 3)

B:
(2, 4)
(8, 9)
(1, 3)
(2, 7)
(2, 9)
(4, 6)
(4, 9)

X = COGROUP A BY f1, B BY $0;

(1, {(1, 2, 3)}, {(1, 3)})
(2, {}, {(2, 4), (2, 7), (2, 9)})
(4, {(4, 2, 1), (4, 3, 3)}, {(4, 6),(4, 9)})
(7, {(7, 2, 5)}, {})
(8, {(8, 3, 4), (8, 4, 3)}, {(8, 9)})

ORDER. . .BY

- Use the ORDER…BY operator to sort a relation based on one or more fields
- Basic syntax:

```
alias = ORDER alias BY field_alias [ASC|DESC];
```

- Example:

```
DUMP alias1;
(1,2,3) (4,2,1) (8,3,4) (4,3,3) (7,2,5) (8,4,3)
alias2 = ORDER alias1 BY col3 DESC;
DUMP alias2;
(7,2,5) (8,3,4) (1,2,3) (4,3,3) (8,4,3) (4,2,1)
```

DISTINCT. . .

- Use the DISTINCT operator to remove duplicate tuples in a relation.
- Basic syntax:

```
alias2 = DISTINCT alias1;
```

- Example:

```
DUMP alias1;
(8,3,4) (1,2,3) (4,3,3) (4,3,3) (1,2,3)
alias2= DISTINCT alias1;
DUMP alias2;
(8,3,4) (1,2,3) (4,3,3)
```

Relational Operators

- FLATTEN
  - Used to un-nest tuples as well as bags
- INNER JOIN
  - Used to perform an inner join of two or more relations based on common field values
- OUTER JOIN
  - Used to perform left, right or full outer joins
- SPLIT
  - Used to partition the contents of a relation into two or more relations
- SAMPLE
  - Used to select a random data sample with the stated sample size

INNER JOIN. . .

- Use the JOIN operator to perform an inner, equi-join join of two or more relations based on common field values
- The JOIN operator always performs an inner join
- Inner joins ignore null keys
  - Filter null keys before the join
- JOIN and COGROUP operators perform similar functions
  - JOIN creates a flat set of output records
  - COGROUP creates a nested set of output records

INNER JOIN Example

```
DUMP Alias1;
    (1,2,3)
    (4,2,1)
    (8,3,4)
    (4,3,3)
    (7,2,5)
    (8,4,3)
DUMP Alias2;
    (2,4)
    (8,9)
    (1,3)
    (2,7)
    (2,9)
    (4,6)
    (4,9)
```

```
Join Alias1 by Col1 to
Alias2 by Col1
    Alias3 = JOIN Alias1 BY
    Col1, Alias2 BY Col1;

Dump Alias3;
    (1,2,3,1,3)
    (4,2,1,4,6)
    (4,3,3,4,6)
    (4,2,1,4,9)
    (4,3,3,4,9)
    (8,3,4,8,9)
    (8,4,3,8,9)
```

OUTER JOIN. . .

- Use the OUTER JOIN operator to perform left, right, or full outer joins
  - Pig Latin syntax closely adheres to the SQL standard
- The keyword OUTER is optional
  - keywords LEFT, RIGHT and FULL will imply left outer, right outer and full outer joins respectively
- Outer joins will only work provided the relations which need to produce nulls (in the case of non-matching keys) have schemas
- Outer joins will only work for two-way joins
  - To perform a multi-way outer join perform multiple two-way outer join statements

User-Defined Functions

- Natively written in Java, packaged as a jar file
  - Other languages include Jython, JavaScript, Ruby, Groovy, and Python
- Register the jar with the REGISTER statement
- Optionally, alias it with the DEFINE statement

```
REGISTER /src/myfunc.jar;
A = LOAD 'students';
B = FOREACH A GENERATE myfunc.MyEvalFunc($0);
```

DEFINE

- DEFINE can be used to work with UDFs and also streaming commands
  - Useful when dealing with complex input/output formats

```
/* read and write comma-delimited data */
DEFINE Y 'stream.pl' INPUT(stdin USING PigStreaming(','))
    OUTPUT(stdout USING PigStreaming(','));
A = STREAM X THROUGH Y;

/* Define UDFs to a more readable format */
DEFINE MAXNUM org.apache.pig.piggybank.evaluation.math.MAX;
A = LOAD ‘student_data’ AS (name:chararray, gpa1:float, gpa2:double);
B = FOREACH A GENERATE name, MAXNUM(gpa1, gpa2);
DUMP B;
```

Example Pig Script

```
-- Load the content of a file into a pig bag named 'input_lines'
input_lines = LOAD 'CHANGES.txt' AS (line:chararray);

-- Extract words from each line and put them into a pig bag named 'words'
words = FOREACH input_lines GENERATE FLATTEN(TOKENIZE(line)) AS word;

-- filter out any words that are just white spaces
filtered_words = FILTER words BY word MATCHES '\\w+';

-- create a group for each word
word_groups = GROUP filtered_words BY word;

-- count the entries in each group
word_count = FOREACH word_groups GENERATE COUNT(filtered_words) AS count, group AS
word;

-- order the records by count
ordered_word_count = ORDER word_count BY count DESC;

-- Store the results ( executes the pig script )
STORE ordered_word_count INTO 'output';
```

PageRank in Pig

```
previous_pagerank = LOAD ‘$docs_in’ USING PigStorage()
  AS (url: chararray, pagerank: float,
      links:{link: (url: chararray)});

outbound_pagerank = FOREACH previous_pagerank
  GENERATE pagerank / COUNT(links) AS pagerank,
  FLATTEN(links) AS to_url;

new_pagerank =
    FOREACH ( COGROUP outbound_pagerank
    BY to_url, previous_pagerank BY url INNER )
    GENERATE group AS url,
      (1 – $d) + $d * SUM(outbound_pagerank.pagerank) AS pagerank,
      FLATTEN(previous_pagerank.links) AS links;

STORE new_pagerank INTO ‘$docs_out’ USING PigStorage();
```

Oh, the iterative part too…

```
#!/usr/bin/python
from org.apache.pig.scripting import *
P = Pig.compile(""" Pig part goes here """)

params = { ‘d’: ‘0.5’, ‘docs_in’: ‘data/pagerank_data_simple’ }

for i in range(10):
  out = "out/pagerank_data_" + str(i + 1)
  params["docs_out"] = out
  Pig.fs("rmr " + out)
  stats = P.bind(params).runSingle()
  if not stats.isSuccessful():
    raise ‘failed’
  params["docs_in"] = out
```

From: http://techblug.wordpress.com/2011/07/29/pagerank-implementation-in-pig/

References

- http://pig.apache.org

Apache Hive

Based on Slides by Adam Shook

What Is Hive?

- Developed by Facebook and a top-level Apache project
- A data warehousing infrastructure based on Hadoop
- Immediately makes data on a cluster available to non-Java programmers via SQL like queries
- Built on HiveQL (HQL), a SQL-like query language
- Interprets HiveQL and generates MapReduce jobs that run on the cluster
- Enables easy data summarization, ad-hoc reporting and querying, and analysis of large volumes of data

What Hive Is Not

- Hive, like Hadoop, is designed for batch processing of large datasets
- Not an OLTP or real-time system
- Latency and throughput are both high compared to a traditional RDBMS
  - Even when dealing with relatively small data (<100 MB)

Data Hierarchy

- Hive is organised hierarchically into:
  - Databases: namespaces that separate tables and other objects
  - Tables: homogeneous units of data with the same schema
    - Analogous to tables in an RDBMS
  - Partitions: determine how the data is stored
    - Allow efficient access to subsets of the data
  - Buckets/clusters
    - For sub-sampling within a partition
    - Join optimization

HiveQL

- HiveQL / HQL provides the basic SQL-like operations:
  - Select columns using SELECT
  - Filter rows using WHERE
  - JOIN between tables
  - Evaluate aggregates using GROUP BY
  - Store query results into another table
  - Download results to a local directory (i.e., export from HDFS)
  - Manage tables and queries with CREATE, DROP, and ALTER

Primitive Data Types

Type	Comments
TINYINT, SMALLINT, INT, BIGINT	1, 2, 4 and 8-byte integers
BOOLEAN	TRUE/FALSE
FLOAT, DOUBLE	Single and double precision real numbers
STRING	Character string
TIMESTAMP	Unix-epoch offset *or* datetime string
DECIMAL	Arbitrary-precision decimal
BINARY	Opaque; ignore these bytes

Complex Data Types

Type	Comments
STRUCT	A collection of elements If S is of type STRUCT {a INT, b INT}: S.a returns element a
MAP	Key-value tuple If M is a map from 'group' to GID: M['group'] returns value of GID
ARRAY	Indexed list If A is an array of elements ['a','b','c']: A[0] returns 'a'

HiveQL Limitations

- HQL only supports equi-joins, outer joins, left semi-joins
- Because it is only a shell for Map-Reduce, complex queries can be hard to optimise
- Missing large parts of full SQL specification:
  - HAVING clause in SELECT
  - Correlated sub-queries
  - Sub-queries outside FROM clauses
  - Updatable or materialized views
  - Stored procedures

Hive Metastore

- Stores Hive metadata
- Default metastore database uses Apache Derby
- Various configurations:
  - Embedded (in-process metastore, in-process database)
    - Mainly for unit tests
  - Local (in-process metastore, out-of-process database)
    - Each Hive client connects to the metastore directly
  - Remote (out-of-process metastore, out-of-process database)
    - Each Hive client connects to a metastore server, which connects to the metadata database itself

Hive Warehouse

- Hive tables are stored in the Hive "warehouse"
  - Default HDFS location: /user/hive/warehouse
- Tables are stored as sub-directories in the warehouse directory
- Partitions are subdirectories of tables
- External tables are supported in Hive
- The actual data is stored in flat files

Hive Schemas

- Hive is schema-on-read
  - Schema is only enforced when the data is read (at query time)
  - Allows greater flexibility: same data can be read using multiple schemas
- Contrast with an RDBMS, which is schema-on-write
  - Schema is enforced when the data is loaded
  - Speeds up queries at the expense of load times

Create Table Syntax

```
CREATE TABLE table_name
    (col1 data_type,
     col2 data_type,
     col3 data_type,
     col4 datatype )
   ROW FORMAT DELIMITED
   FIELDS TERMINATED BY ','
   STORED AS format_type;
```

Simple Table

```
CREATE TABLE page_view
    (viewTime INT,
     userid BIGINT,
     page_url STRING,
     referrer_url STRING,
     ip STRING COMMENT 'IP Address of the User' )
   ROW FORMAT DELIMITED
   FIELDS TERMINATED BY '\t'
   STORED AS TEXTFILE;
```

More Complex Table

```
CREATE TABLE employees  (
    (name STRING,
    salary FLOAT,
    subordinates ARRAY<STRING>,
    deductions MAP<STRING, FLOAT>,
    address STRUCT<street:STRING,
                   city:STRING,
                   state:STRING,
                   zip:INT>)
  ROW FORMAT DELIMITED
  FIELDS TERMINATED BY '\t'
  STORED AS TEXTFILE;
```

External Table

```
CREATE EXTERNAL TABLE page_view_stg
    (viewTime INT,
     userid BIGINT,
     page_url STRING,
     referrer_url STRING,
     ip STRING COMMENT 'IP Address of the User')
   ROW FORMAT DELIMITED
   FIELDS TERMINATED BY '\t'
   STORED AS TEXTFILE
   LOCATION '/user/staging/page_view';
```

More About Tables

- CREATE TABLE
  - LOAD: file moved into Hive's data warehouse directory
  - DROP: both metadata and data deleted
- CREATE EXTERNAL TABLE
  - LOAD: no files moved
  - DROP: only metadata deleted
  - Use this when sharing with other Hadoop applications, or when you want to use multiple schemas on the same data

Partitioning

- Can make some queries faster
- Divide data based on partition column
- Use PARTITION BY clause when creating table
- Use PARTITION clause when loading data
- SHOW PARTITIONS will show a table's partitions

Bucketing

- Can speed up queries that involve sampling the data
  - Sampling works without bucketing, but Hive has to scan the entire dataset
- Use CLUSTERED BY when creating table
  - For sorted buckets, add SORTED BY
- To query a sample of your data, use TABLESAMPLE

Browsing Tables And Partitions

Command	Comments
`SHOW TABLES;`	Show all the tables in the database
`SHOW TABLES 'page.*';`	Show tables matching the specification (uses regex syntax)
`SHOW PARTITIONS page_view;`	Show the partitions of the page_view table
`DESCRIBE page_view;`	List columns of the table
`DESCRIBE EXTENDED page_view;`	More information on columns (useful only for debugging)
`DESCRIBE page_view PARTITION (ds='2008-10-31');`	List information about a partition

Loading Data

- Use LOAD DATA to load data from a file or directory
  - Will read from HDFS unless LOCAL keyword is specified
  - Will append data unless OVERWRITE specified
  - PARTITION required if destination table is partitioned

```
LOAD DATA LOCAL INPATH '/tmp/pv_2008-06-8_us.txt'
  OVERWRITE INTO TABLE page_view
  PARTITION (date='2008-06-08', country='US')
```

Inserting Data

- Use INSERT to load data from a Hive query
  - Will append data unless OVERWRITE specified
  - PARTITION required if destination table is partitioned

```
FROM page_view_stg pvs
  INSERT OVERWRITE TABLE page_view
  PARTITION (dt='2008-06-08', country='US')
  SELECT pvs.viewTime, pvs.userid,
         pvs.page_url, pvs.referrer_url
  WHERE pvs.country = 'US';
```

Loading And Inserting Data: Summary

Use this	For this purpose
`LOAD`	Load data from a file or directory
`INSERT`	Load data from a query • One partition at a time • Use multiple INSERTs to insert into multiple partitions in the one query
`CREATE TABLE AS (CTAS)`	Insert data while creating a table
Add/modify external file	Load new data into external table

Sample Select Clauses

- Select from a single table

```
SELECT *
   FROM sales
   WHERE amount > 10 AND
            region = "US";
```

- Select from a partitioned table

```
SELECT page_views.*
 FROM page_views
 WHERE page_views.date >= '2008-03-01' AND
      page_views.date <= '2008-03-31'
```

Relational Operators

- ALL and DISTINCT
  - Specify whether duplicate rows should be returned
  - ALL is the default (all matching rows are returned)
  - DISTINCT removes duplicate rows from the result set
- WHERE
  - Filters by expression
  - Does not support IN, EXISTS or sub-queries in the WHERE clause
- LIMIT
  - Indicates the number of rows to be returned

Relational Operators

- GROUP BY
  - Group data by column values
  - Select statement can only include columns included in the GROUP BY clause
- ORDER BY / SORT BY
  - ORDER BY performs total ordering
    - Slow, poor performance
  - SORT BY performs partial ordering
    - Sorts output from each reducer

- Hive looks similar to an SQL database
- Relational join on two tables:
  - Table of word counts from Shakespeare collection
  - Table of word counts from the bible

```
SELECT s.word, s.freq, k.freq FROM shakespeare s
  JOIN bible k ON (s.word = k.word) WHERE s.freq >= 1 AND k.freq >= 1
  ORDER BY s.freq DESC LIMIT 10;
```

the	25848	62394
I	23031	8854
and	19671	38985
to	18038	13526
of	16700	34654
a	14170	8057
you	12702	2720
my	11297	4135
in	10797	12445
is	8882	6884

Hive: Behind the Scenes

```
SELECT s.word, s.freq, k.freq FROM shakespeare s
  JOIN bible k ON (s.word = k.word) WHERE s.freq >= 1 AND k.freq >= 1
  ORDER BY s.freq DESC LIMIT 10;
```

(Abstract Syntax Tree)

```
(TOK_QUERY (TOK_FROM (TOK_JOIN (TOK_TABREF shakespeare s) (TOK_TABREF bible k) (= (. (TOK_TABLE_OR_COL s) word) (.
(TOK_TABLE_OR_COL k) word)))) (TOK_INSERT (TOK_DESTINATION (TOK_DIR TOK_TMP_FILE)) (TOK_SELECT (TOK_SELEXPR (.
(TOK_TABLE_OR_COL s) word)) (TOK_SELEXPR (. (TOK_TABLE_OR_COL s) freq)) (TOK_SELEXPR (. (TOK_TABLE_OR_COL k) freq))) (TOK_WHERE
(AND (>= (. (TOK_TABLE_OR_COL s) freq) 1) (>= (. (TOK_TABLE_OR_COL k) freq) 1))) (TOK_ORDERBY (TOK_TABSORTCOLNAMEDESC (.
(TOK_TABLE_OR_COL s) freq))) (TOK_LIMIT 10)))
```

(one or more of MapReduce jobs)

Hive: Behind the Scenes

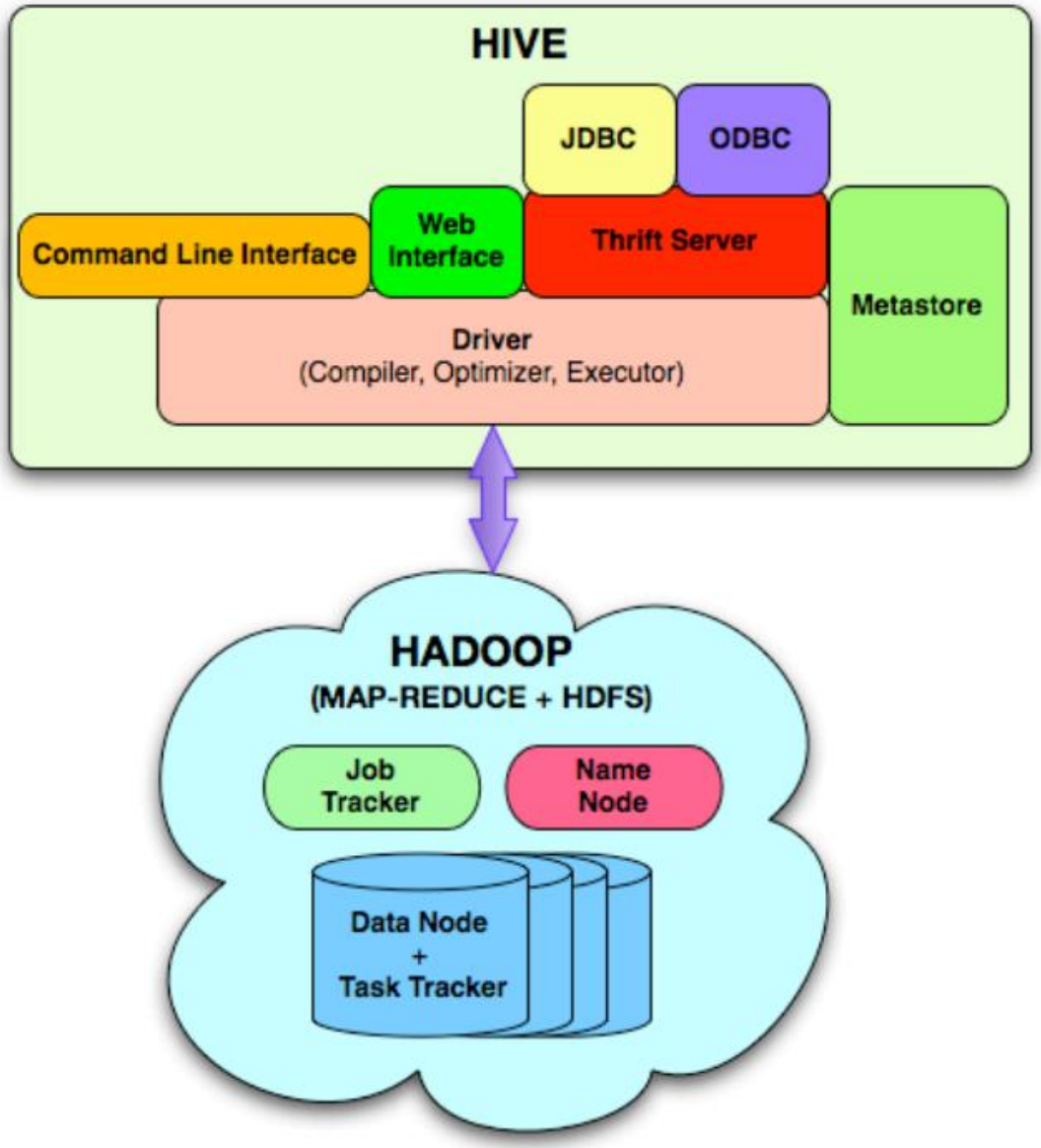
```
STAGE DEPENDENCIES:
  Stage-1 is a root stage
  Stage-2 depends on stages: Stage-1
  Stage-0 is a root stage

STAGE PLANS:
  Stage: Stage-1
    Map Reduce
      Alias -> Map Operator Tree:
        s
          TableScan
            alias: s
            Filter Operator
              predicate:
                  expr: (freq >= 1)
                  type: boolean
              Reduce Output Operator
                key expressions:
                      expr: word
                      type: string
                sort order: +
                Map-reduce partition columns:
                      expr: word
                      type: string
                tag: 0
                value expressions:
                      expr: freq
                      type: int
                      expr: word
                      type: string
        k
          TableScan
            alias: k
            Filter Operator
              predicate:
                  expr: (freq >= 1)
                  type: boolean
              Reduce Output Operator
                key expressions:
                      expr: word
                      type: string
                sort order: +
                Map-reduce partition columns:
                      expr: word
                      type: string
                tag: 1
                value expressions:
                      expr: freq
                      type: int
      Reduce Operator Tree:
        Join Operator
          condition map:
               Inner Join 0 to 1
          condition expressions:
            0 {VALUE._col0} {VALUE._col1}
            1 {VALUE._col0}
          outputColumnNames: _col0, _col1, _col2
          Filter Operator
            predicate:
                expr: ((_col0 >= 1) and (_col2 >= 1))
                type: boolean
            Select Operator
              expressions:
                    expr: _col1
                    type: string
                    expr: _col0
                    type: int
                    expr: _col2
                    type: int
              outputColumnNames: _col0, _col1, _col2
              File Output Operator
                compressed: false
                GlobalTableId: 0
                table:
                    input format: org.apache.hadoop.mapred.SequenceFileInputFormat
                    output format: org.apache.hadoop.hive.ql.io.HiveSequenceFileOutputFormat

  Stage: Stage-2
    Map Reduce
      Alias -> Map Operator Tree:
        hdfs://localhost:8022/tmp/hive-training/364214370/10002
            Reduce Output Operator
              key expressions:
                    expr: _col1
                    type: int
              sort order: -
              tag: -1
              value expressions:
                    expr: _col0
                    type: string
                    expr: _col1
                    type: int
                    expr: _col2
                    type: int
      Reduce Operator Tree:
        Extract
          Limit
            File Output Operator
              compressed: false
              GlobalTableId: 0
              table:
                  input format: org.apache.hadoop.mapred.TextInputFormat
                  output format: org.apache.hadoop.hive.ql.io.HiveIgnoreKeyTextOutputFormat


  Stage: Stage-0
    Fetch Operator
      limit: 10
```

Hive Architecture



References

- http://hive.apache.org