Pig Latin: A Not-So-Foreign Language for Data Processing

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What is Pig Latin?

Apache Pig

- A data processing language developed at Yahoo!
- Has both procedural and declarative aspects
- Compiled by the accompanying Pig system
- Uses the mapReduce system Hadoop in its execution
- Comes with a rich debugging environment

A Quick Example Case

Task: Given a table with the name url, and fields (url, category, and pagerank), find the average pagerank of each category for all urls with a pagerank greater than 0.2, and where the category has greater than 100,000 pages.

SQL Implementation:

```
SELECT category, AVG(pagerank)
FROM urls WHERE pagerank > 0.2
GROUP BY category HAVING COUNT (*) > 10^6
```

A Quick Example Case

Task: Given a table with the Name url, and fields (url, category, and pagerank), find the average pagerank each category for all urls with a pagerank greater than 0.2, and where the category has greater than 100,000 pages.

Pig Latin Implementation:

```
good_urls = FILTER urls BY pagerank > 0.2;
groups = GROUP good_urls BY category;
big_groups = FILTER groups BY COUNT(good_urls) > 10^6;
output = FOREACH big_groups GENERATE category, AVG(good_urls.pagerank);
```

Pig System Features and Motivations

Dataflow Language

- Sequence of high-level data transformations
  - "Easier to work with"

```
good_urls = FILTER urls BY pagerank > 0.2;
groups = GROUP good_urls BY category;
big_groups = FILTER groups BY COUNT(good_urls)>10^6;
output = FOREACH big_groups GENERATE
            category, AVG(good_urls.pagerank);
```

- Order of execution is not necessarily fixed
  - System can optimize in most cases

```
spam_urls = FILTER urls BY isSpam(url);
culprit_urls = FILTER spam_urls BY pagerank > 0.8;
```

Quick Start and Interoperability

- Support for Ad-Hoc Analysis
  - Can directly run Pig queries on data
    - No need for lengthy import processes
    - With function to parse the data into tuples
    - Schema is not necessary
  - Can format output of Pig queries
    - Ex. Convert the tuple output into bytes
  - Easy to integrate with other applications

```
good_urls = FILTER urls BY $2 > 0.2;
```

- Workload
  - Read Only
  - Scans (not much indexing, etc)
  - Data is discarded on normal basis

Nested Data Model

- Offers Nested Data Structures
  - As opposed to 1NF (atomic column values)
- Closer to how programmers conceptualize
- Data is often stored in a nested format on disks (read only)
  - Saves compute to break down into 1NF, recombine
- Better fits design paradigm
  - One data transformation per step
- Better support for complex user defined functions.

```
term_info:   (termId, termString, ...)
position_info:   (termId, documentId, position)
```

```
Map<documentId, Set<positions>>
```

UDFs as First-Class Citizens

- Lots of data analytics involves custom processing
  - Spam detection, Search analysis, etc.

- Extensive Support for User Defined Functions
  - Can customize the functionality of all processing steps
    - Grouping, filtering, joining, and per-tuple
    - One type of UDF which covers everything
      - SQL: Scalar for SELECT, Aggregation needs GROUP BY
    - Input and output can be non-scalar (nested)

Ryan Ding

UDFs as First-Class Citizens

- Consider the original example from the Introduction
  - Task: Given a table with the Name url, and fields (url, category, and pagerank), find the average pagerank each category for all urls with a pagerank greater than 0.2, and where the category has greater than 100,000 pages.

- Say we only want to average the top 10 urls for each category (based on pagerank)…

```
groups = GROUP urls BY category;
output = FOREACH groups GENERATE
                 category, top10(urls);
```

- top10(urls) takes a set of urls and returns a set of 10 urls
  - Implemented in Java (initially)

UDFs as First-Class Citizens

```
good_urls = FILTER urls BY pagerank > 0.2;
groups = GROUP good_urls BY category;
big_groups = FILTER groups BY COUNT(good_urls) > 10^6;
top_urls = FOREACH big_groups GENERATE category, top10(good_urls)
output = FOREACH big_groups GENERATE category, AVG(top_urls.pagerank);
```

Parallelism Required

- Lots of data
  - Parallelism is essentially required

- Has only small set of primitives that can be parallelized
  - LOAD, FOREACH, etc. (expanded in later sections)

- Does not natively support non-equal joins, correlated subqueries
  - Can still be manually implemented through UDFs, but has very limited performance

Ryan Ding

Debugging Environment

- Can take a long time to process queries
  - Has "novel" debugger
  - Prints out Example table after each step which shows structure of output
    - Expanded in future sections

visits:	(Amy, cnn.com, 8am)
	(Amy, frogs.com, 9am)
	(Fred, snails.com, 11am)
pages:	(cnn.com, 0.8)
	(frogs.com, 0.8)
	(snails.com, 0.3)

Pig Latin Language

Data Model

- 4 types of data
  - Atom: single atomic value;
  - Tuple: sequence of fields, each can be a different type;
  - Bag: A collection of tuples, can have duplicates, and each tuple can be a different structure;
  - Map: A collection of key -> value mappings. Key is required to be atomic.

$$t = \left(\text{'alice'}, \left\{ \begin{array}{c} (\text{'lakers'}, 1) \\ (\text{'iPod'}, 2) \end{array} \right\}, [\text{'age'} \rightarrow 20] \right)$$

Let fields of tuple t be called f1, f2, f3

Expression Type	Example	Value for t
Constant	'bob'	Independent of t
Field by position	$0	'alice'
Field by name	f3	['age' → 20]
Projection	f2.$0	{ ('lakers') ('iPod') }
Map Lookup	f3#'age'	20
Function Evaluation	SUM(f2.$1)	1 + 2 = 3
Conditional Expression	f3#'age'>18? 'adult':'minor'	'adult'
Flattening	FLATTEN(f2)	'lakers', 1 'iPod', 2

Table 1: Expressions in Pig Latin.

A tuple with an atom, a bag, and a map.

Zeyu Chang

Command: LOAD

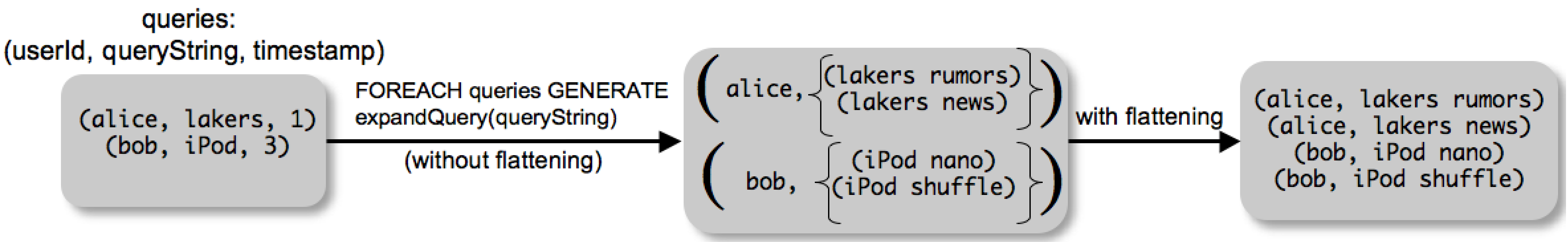
- Input:
  - The data file, e.g. "query_log.txt"
  - Deserialize function, e.g. "myLoad"
  - Tuple configuration

```
queries  =  LOAD 'query_log.txt'
            USING myLoad()
            AS (userId, queryString, timestamp);
```

- Output:
  - A *handle* variable to the LOAD command

Command: FOREACH

- Apply processing to every tuple of a data set
- This could lead to nesting in the processed data
- "FLATTEN" is used to eliminate this nesting



Zeyu Chang

Command: FILTER

- Filters away some of the data base on some condition
- Condition can be arbitrary:
  - Comparison operators: ==, !=, eq, neq, >=, etc.
  - Logical operators: AND, OR, NOT
  - User defined functions

- The following two achieves the same objective:
  - `real_queries = FILTER queries BY userId neq 'bot';`
  - `real_queries = FILTER queries BY NOT isBot(userId);`

Command: COGROUP vs JOIN

- To group tuples from one or more data sets via some relation
- COGROUP: Generally, outputs a tuple for each group
- GROUP: A special case of COGROUP, where group is perform on only one data set
- JOIN: Equivalent to performing a cross product after executing COGROUP

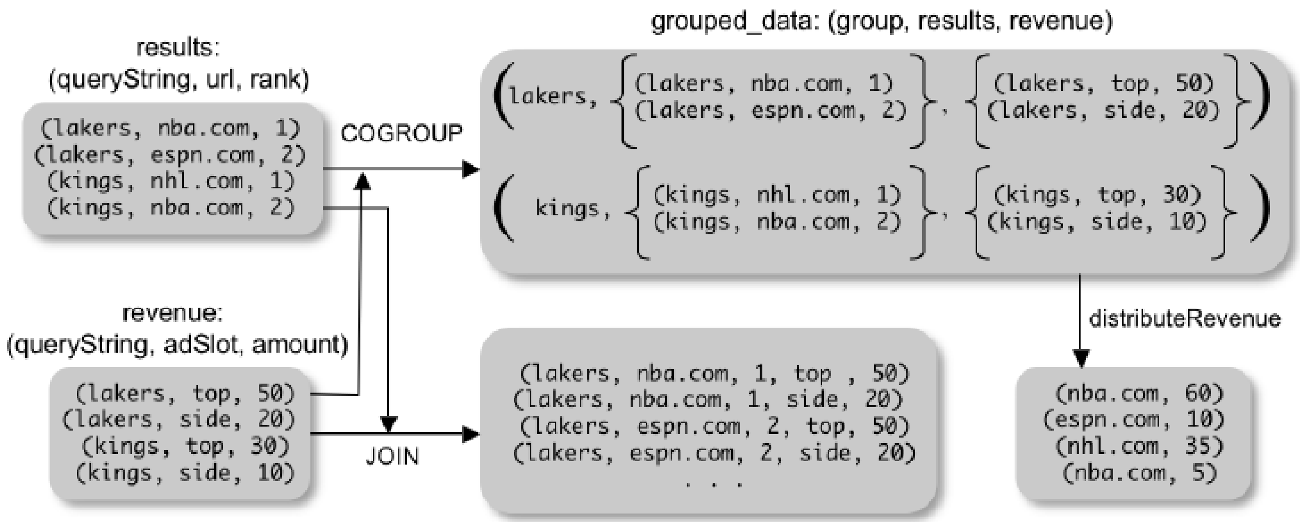


Figure 2: COGROUP versus JOIN.

Zeyu Chang

Other commands

- Similar commands to SQL
  - UNION: the union of two bags
  - CROSS: the cross product of two bags
  - ORDER (BY): order a bag by specific fields
  - DISTINCT: eliminate duplicates from the bag

- `ordered_result = ORDER query_revenues BY totalRevenue;`

Zeyu Chang

Nested operations

- Pig Latin allows some commands to be nested within a FOREACH command

```
grouped_revenue = GROUP revenue BY queryString;
query_revenues = FOREACH grouped_revenue{
                     top_slot = FILTER revenue BY
                                adSlot eq 'top';
                     GENERATE queryString,
                              SUM(top_slot.amount),
                              SUM(revenue.amount);
                 };
```

Command: STORE

- Store a Pig Latin expression sequence into a file

- `STORE query_revenues INTO 'myoutput' USING myStore();`
    - Serialize query_revenues using a custom serializer myStore
    - The serialized result is stored to "myoutput"

Pig Latin Implementation

IMPLEMENTATION

- **Pig System**: An open-source platform (Apache project) that implements Pig Latin.
- **Hadoop Integration**: Leverages Hadoop's scalable **MapReduce** framework.
- **Compilation & Execution Process:**
  - **Pig Latin scripts** are compiled into **logical plan**.
  - The **logical plans** are further compiled into **MapReduce jobs**.
  - Compiled **MapReduce jobs** are executed on a **Hadoop cluster**.

Building a Logical Plan

- **Pig Interpreter**:
  - **Parses** Pig Latin commands as they are issued by the user.
  - Handles **syntax checking** and provides error messages for issues.
  - **Validates** that **variables** (bags, relations) used are previously defined.
  - Builds a **logical plan for every bag.**
- **Logical Plans for Bags**:
  - **Definition**: An abstract representation of the data flow to produce bags.
  - **Example**:
    - Command: `c = COGROUP a BY queryString, b BY queryString`
    - Logical plan for `c` includes a cogroup operation using logical plans of `a` and `b`.
- **Lazy Execution**: Execution is deferred until a STORE command is invoked.
- **Platform Independence**: Logical plan construction is independent of the execution platform.

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Map-Reduce Plan Compilation

- Each COGROUP operation becomes its own MapReduce job.
- **Map Function**: Assigns keys based on the BY clause(s).
- **Reduce Function**: Forms grouped tuples and **creates nested bags** for cogroup data.

```
grouped_data  =  COGROUP results BY queryString,
                         revenue BY queryString;
```

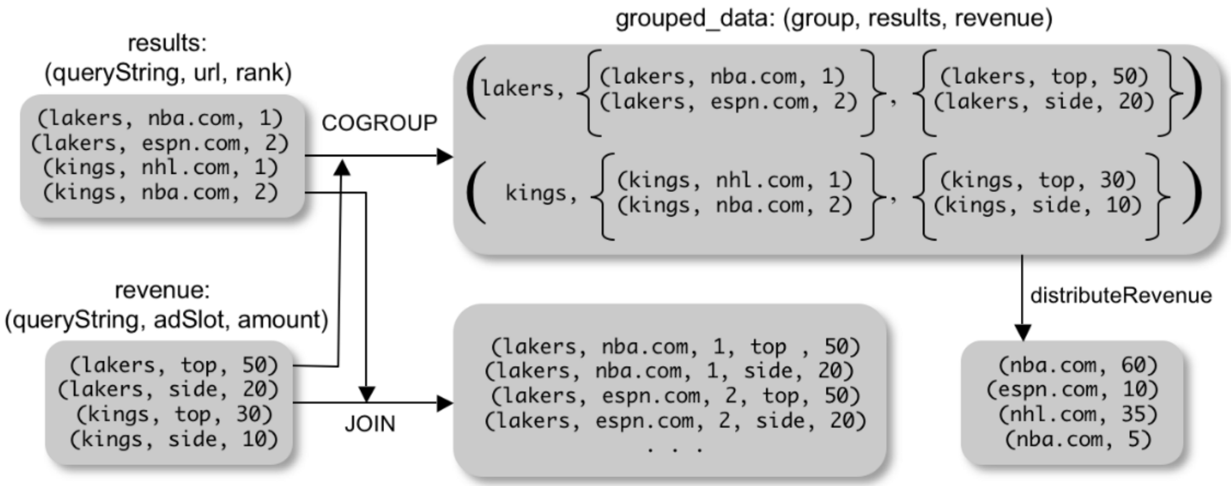


Figure 2: COGROUP versus JOIN.

Map-Reduce Plan Compilation

- **Operation Placement**:
  - **`FILTER`** and **`FOREACH`** commands from **`LOAD`** to the first `COGROUP` are incorporated into the **map** function.
  - Operations between subsequent `COGROUP` are pushed into the **reduce** function of the **preceding** `COGROUP`.
- **Limitations:**
  - **Intermediate data** must be **materialized** between jobs.
  - **Rigid** MapReduce model may not efficiently handle all Pig Latin operations.

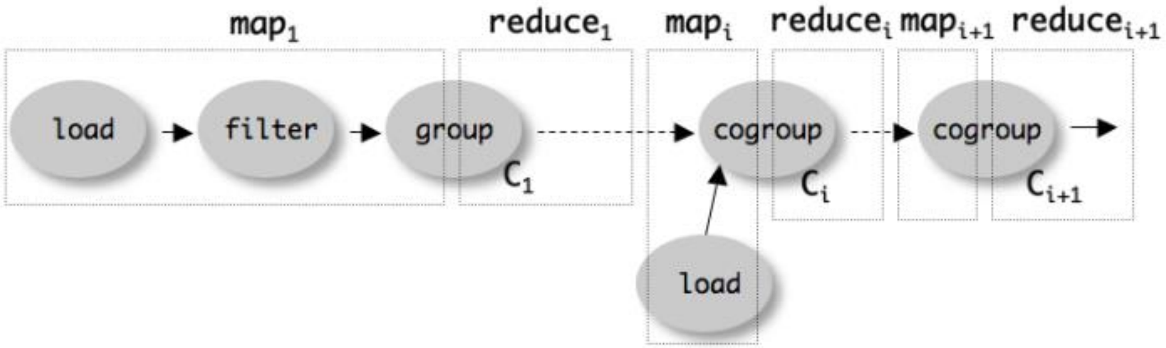


Figure 3: Map-reduce compilation of Pig Latin.

Efficiency With Nested Bags

- **Avoiding Materialization of Large Nested Bags**:
  - **Algebraic Functions for Aggregation**:
    - Functions **structured as a tree of subfunctions** operating on data subsets (e.g., `COUNT`, `SUM`, `MIN`, `MAX`, `AVERAGE`, `VARIANCE`).
    - Pig utilizes Hadoop's **combiner** feature for efficient aggregation.
  - **Handling Non-Algebraic Functions**:
    - Functions like **`MEDIAN` or custom UDFs** that are not algebraic require full materialization.
    - Pig spills large nested bags to disk when they can't fit in memory.

Other Features and Considerations

Debugging Environment – Pig Pen. But, why?

- Construction of a program in Pig Latin is repetitive, inefficient for large-scale data
- Traditional Debugging method: Sampling – Create a smaller subset of original data
- Limitations: Difficult to find sample data to test semantics of the program
- Example:

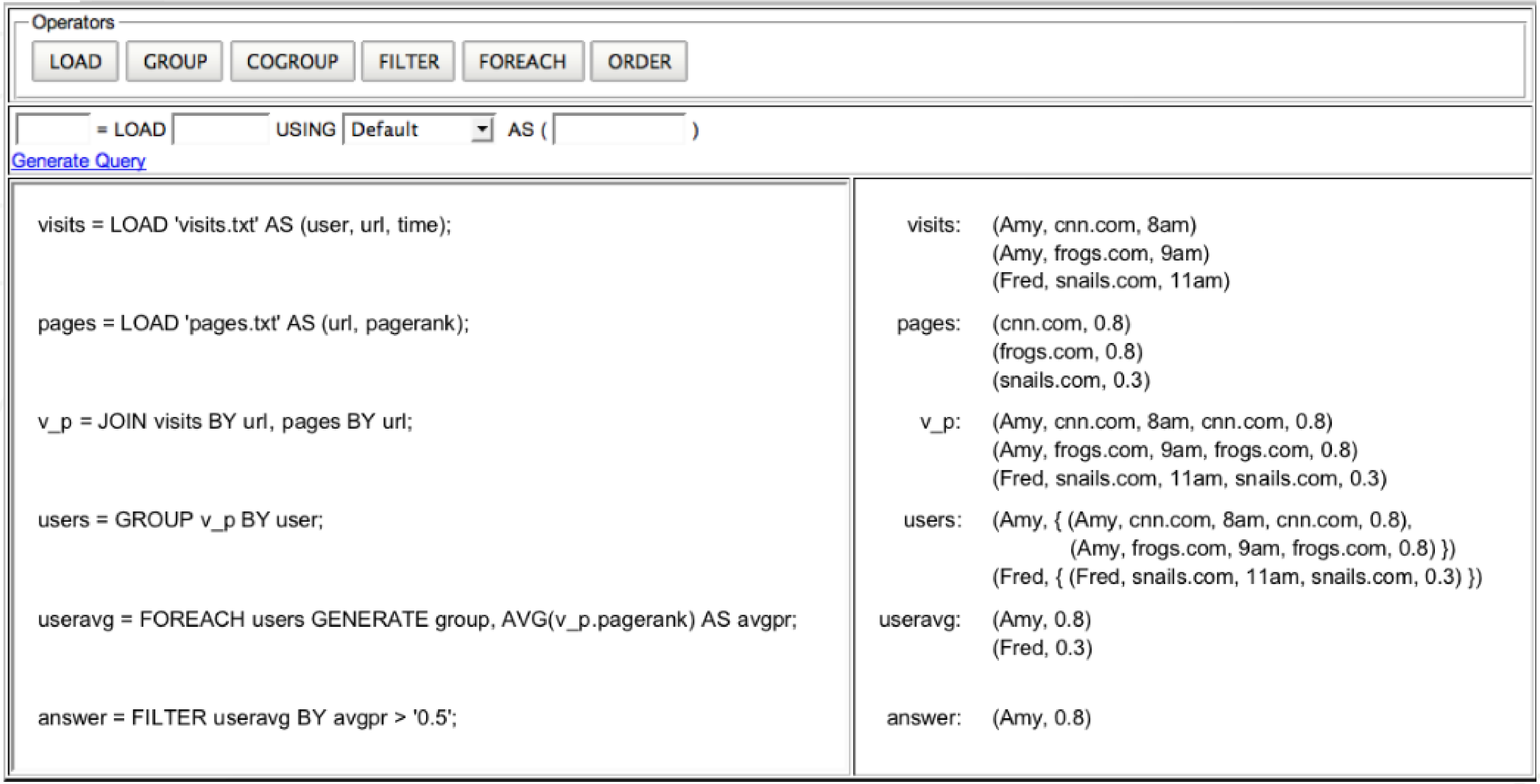
  R1 (x,y)

  R2 (x,z)

  R1 EQUI JOIN R2 might return empty set, if subset of datasets do not contain matching values for column 'x'.

- Hence, Pig Pen: Dynamically constructs side data set
- Advantages: Spot bugs, simplifies writing program incrementally

Pig Pen


Operators
LOAD
GROUP
COGROUP
FILTER
FOREACH
ORDER
= LOAD
USING
Default
AS (
)
Generate Query
visits = LOAD 'visits.txt' AS (user, url, time);
pages = LOAD 'pages.txt' AS (url, pagerank);
v_p = JOIN visits BY url, pages BY url;
users = GROUP v_p BY user;
useravg = FOREACH users GENERATE group, AVG(v_p.pagerank) AS avgpr;
answer = FILTER useravg BY avgpr > '0.5';
visits:
(Amy, cnn.com, 8am)
(Amy, frogs.com, 9am)
(Fred, snails.com, 11am)
pages:
(cnn.com, 0.8)
(frogs.com, 0.8)
(snails.com, 0.3)
v_p:
(Amy, cnn.com, 8am, cnn.com, 0.8)
(Amy, frogs.com, 9am, frogs.com, 0.8)
(Fred, snails.com, 11am, snails.com, 0.3)
users:
(Amy, { (Amy, cnn.com, 8am, cnn.com, 0.8),
(Amy, frogs.com, 9am, frogs.com, 0.8) })
(Fred, { (Fred, snails.com, 11am, snails.com, 0.3) })
useravg:
(Amy, 0.8)
(Fred, 0.3)
answer:
(Amy, 0.8)

Generating Sandbox Dataset

- LOAD command: Sandbox dataset
- Primary Objectives:

1. **Realism**: Subset of actual dataset or synthesized from actual data
2. **Conciseness**: Small as possible, remove redundancies
3. **Completeness**: Illustrate semantics of command

Use-cases

- **Rollup Aggregates:** Calculating various aggregates
  Example: Counting the number of searches per user and computing the average per-user count in web crawls
- **Temporal Analysis:** COGROUP command in Pig is particularly useful for this task as it groups search queries from different time periods, facilitating custom processing.
  Example: Understanding how search query distributions change overtime
- **Session Analysis:** Natural abstraction and manipulation of sessions
  Example: Calculate metrics such as average session length, number of clicks before leaving a website, and variations in click patterns over time

Why is Pig better than OLAP?

- **Scalability and Flexibility**: Directly compute aggregates over large distributed files without the need for prior curation.
- **Ease of Incorporation of Custom Processing**: Easy integration of custom processing steps, such as IP-to-geo mapping and n-gram extraction.
- **Efficiency with Large Datasets:** Orchestrates a sequence of multiple map-reduce jobs.
- **Natural Data Representation**: Manipulate complex data structures/nested data like user sessions.

Related Work

Pig Latin vs. Other Platforms

- **Dynamo**: Focused on transactional key-value storage, not batch analytics like Pig.
- **Dryad**: More high-level than Dryad's low-level DAG model. Pig Latin could potentially compile to Dryad jobs.
- **DryadLINQ**: Similar high-level language, but Pig Latin has a more procedural style.
- **MapReduce**: More flexible than MapReduce's rigid two-step structure. Pig Latin allows chaining multiple operations.
- **Sawzall**: More flexible than Sawzall's fixed map+aggregate structure. Pig Latin supports arbitrary UDFs and operations like joins.
- **NESL**: Pig Latin adds data combination operations (e.g. join, cogroup) on top of nested data model.

Future Work

"Safe" Optimizer:

- Implement optimizations that guarantee performance benefits

Improved User Interfaces

- Develop a "boxes-and-arrows" GUI for visual program specification
- Enhance collaboration features (e.g., sharing program fragments, UDFs)

External Functions Support

- Enable UDFs in scripting languages (e.g., Perl, Python)
- Implement lightweight serialization/deserialization layer

Unified Development Environment

- Integrate control structures (loops, conditionals) into Pig Latin
- Embed Pig Latin into established languages (e.g., Perl, Python) for remote execution through packages
- Create a single environment for:
    - Main program development
    - Pig Latin commands
    - UDF writing

Summary

- Developed by Yahoo! in 2006, became Apache top-level project in 2010
- **Purpose**: High-level platform for analyzing large datasets, bridging SQL and MapReduce
- **Key Features**:
- Pig Latin: Simplified scripting language for data analysis
- Compiles to MapReduce jobs, runs on Hadoop
- Supports complex data types and user-defined functions
- **Current Status**:
- Latest stable release: v0.17.0 (May 2018)
- Open-source, relevant in Hadoop ecosystem
- Competitors: Google BigQuery, Amazon Redshift, Apache Hive, Apache Spark

Study Questions

1) Convert the following SQL query to a Pig Latin script. The SQL query retrieves the names and total sales of each product category from a `sales` table, grouped by category.

```
SELECT category, SUM(amount) as total_sales
FROM sales
GROUP BY category;
```

2) For the below web crawl data, where each record includes `url` and `visit_duration` (in seconds), write a Pig Latin script that categorizes each visit based on the `visit_duration` and outputs the `url`, `visit_duration`, and `category (Long, Medium, Short)` for each visit.

```
http://example.com, 450
http://example.org, 200
http://example.net, 50
http://example.edu, 600
```

Thank You!
Questions?

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