Parallel Programming Models and Languages

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Problem

Writing parallel code is hard for several reasons:

- parallelize computation
- distribute data
- handle failure
- load balancing
- fault tolerance

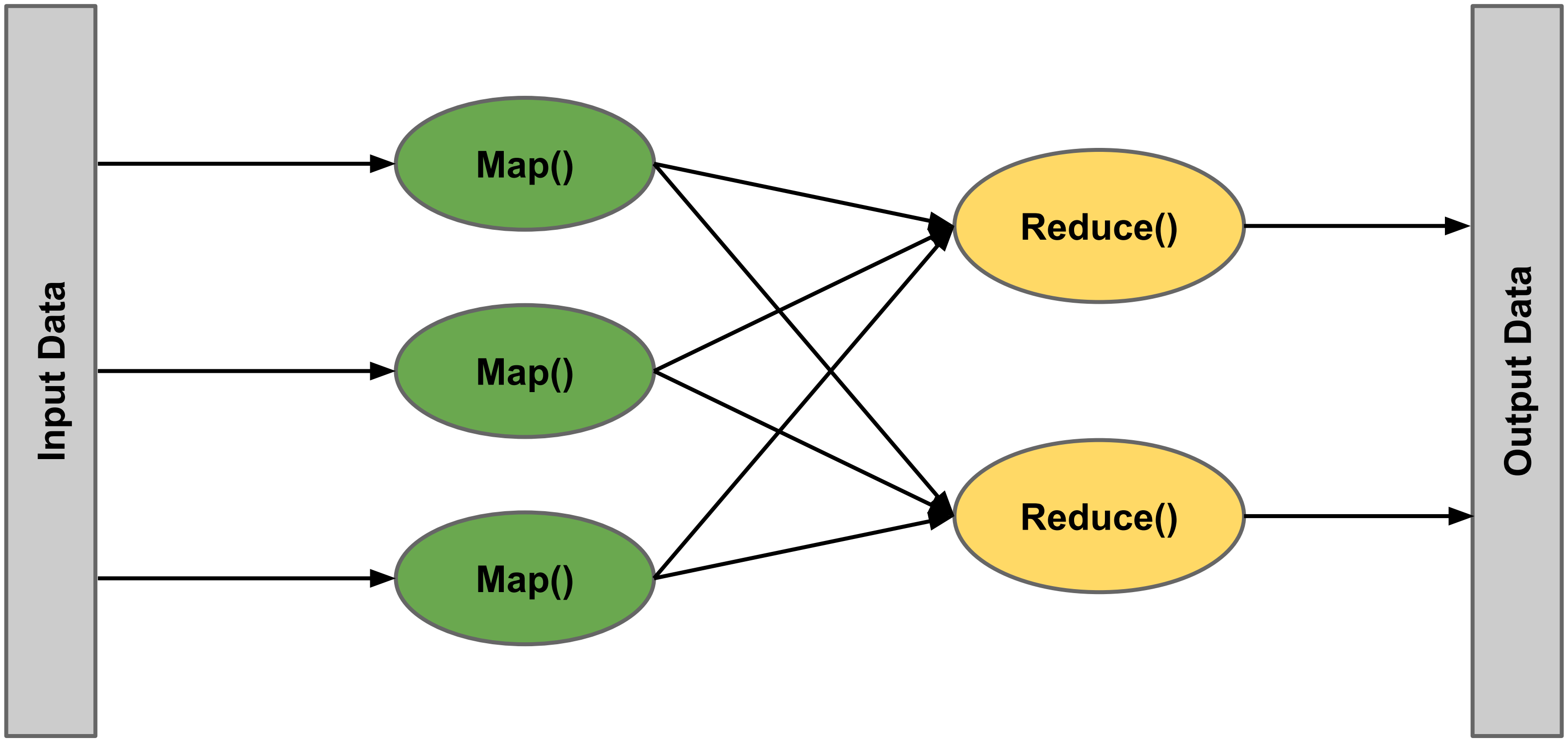
Solution

Uses a library that handle (and hides) all these details and makes the programmer life easier

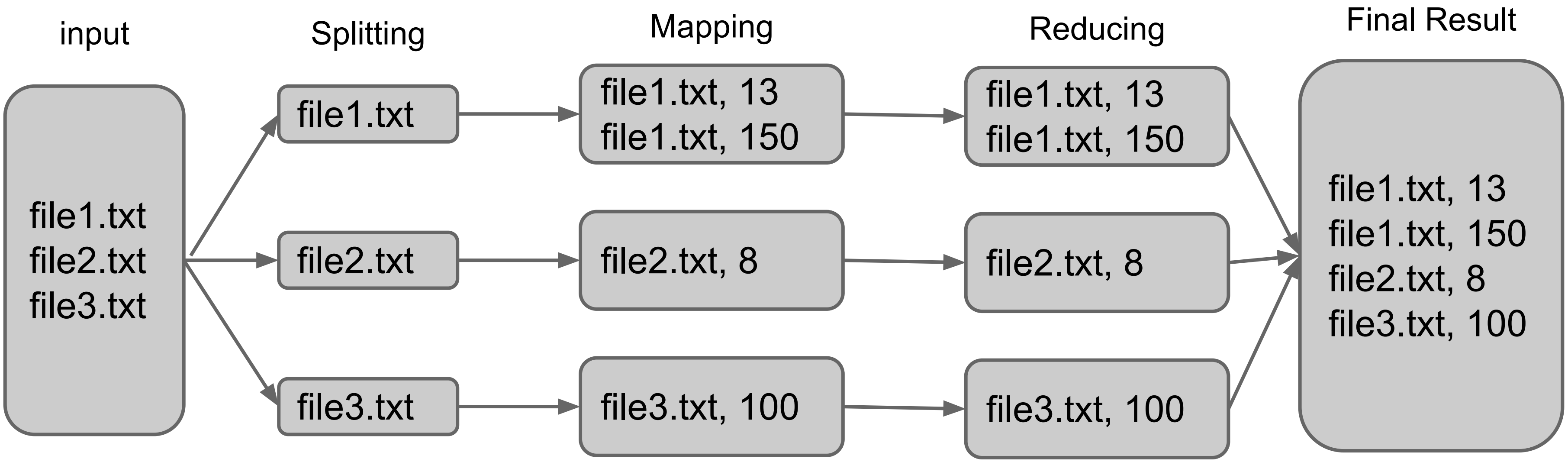
Outline

- MapReduce
- Dryad
- PigLatin

MapReduce



Grep - MapReduce



Benefits for User

- Programmer writes two functions
  - map
  - reduce
- Doesn’t have to worry about distributed computing
  - faults are handled by the system
  - distributing the work

Benefits for System

- Run on commodity hardware
    - fault tolerant
        - unresponsive worker
        - master failure
    - backup tasks

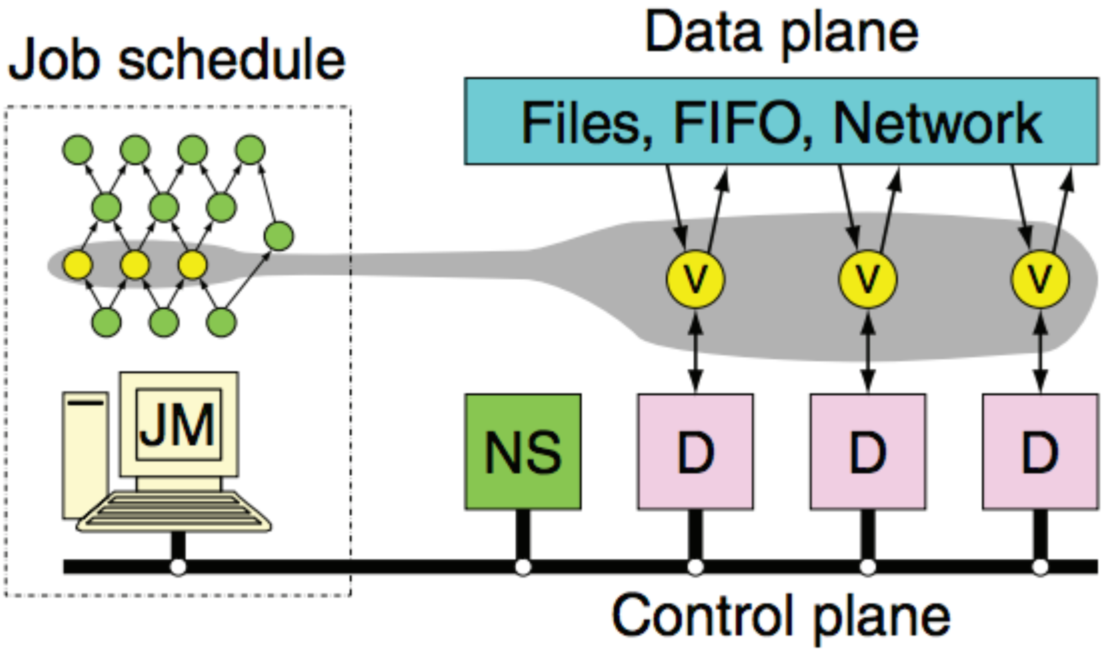
Performance - Grep

- Scanned through 10^{10} 100-byte records
- 1764 workers were assigned
- Entire computation took 150 seconds including 60 sec of startup overhead

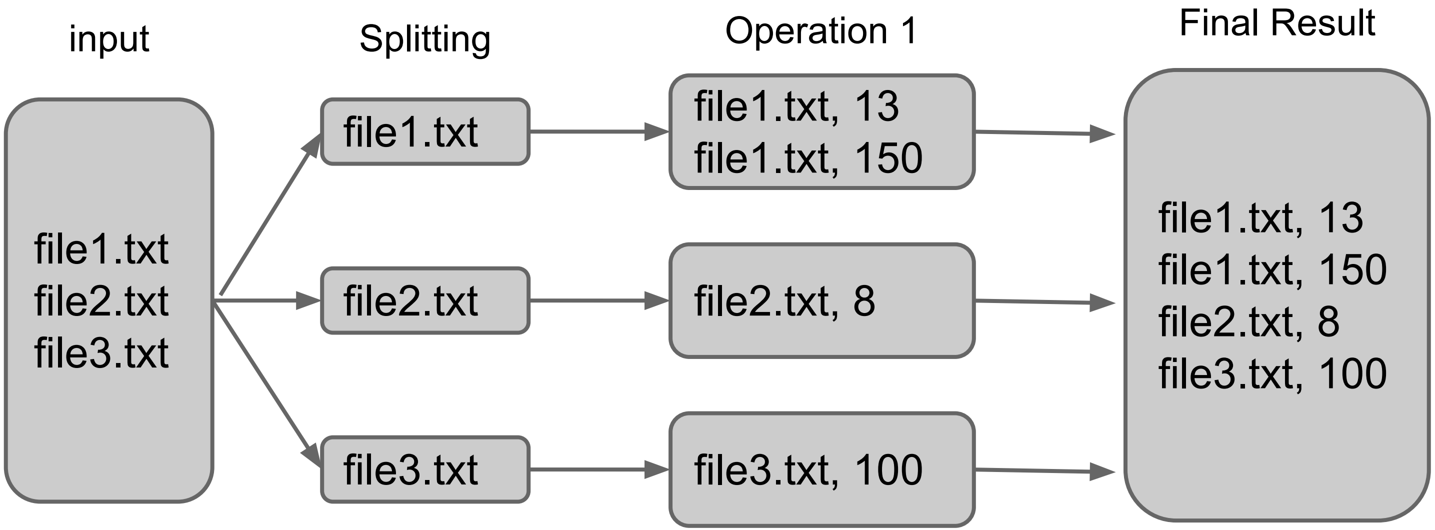
Dryad vs. MapReduce

- Generalization of MapReduce workflow.
- Gives programmer fine-grained control over communication graph
- Steeper learning curve to using API

System Overview



Grep - Dryad



input
Splitting
Operation 1
Final Result
file1.txt
file2.txt
file3.txt
file1.txt
file2.txt
file3.txt
file1.txt, 13
file1.txt, 150
file2.txt, 8
file3.txt, 100
file1.txt, 13
file1.txt, 150
file2.txt, 8
file3.txt, 100

Fault Tolerance

- Job manager informed if a vertex execution fails
- If the process crashes the daemon notifies the job manager.
- If the daemon fails the job manager will get a heartbeat timeout.

PigLatin

Tries to improve the flexibility of Map-Reduce and increase code reusability by using:

- high level declarative querying (similar to SQL)
- low level procedural programming

Example: SQL

SQL:

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

Example: Pig Latin

Pig Latin:

```
urls = LOAD ‘urls_log.txt’ USING myLoad()
       AS (urls, pagerank, category)
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_group GENERATE category,
             AVG(good_urls.pagerank)
```

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LOAD: specifies input data files, how to deserialize and convert into Pig Latin

Example: Pig Latin

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FILTER:
retains only part of the data and discards the rest

Example: Pig Latin

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(CO)GROUP: groups together tuples from more data sets

Example: Pig Latin

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FOREACH: applies some processing to each tuple in the data set

Commands

Every commands only perform one transformation on the data.

The programmer can write finer grained optimizations.

Data Model

- **Atom**: simple atomic values (i.e., `20, ‘alice’`)
- **Tuple**: a sequence of fields of any data type
- **Bag**: a collection of tuples with duplicates and not with the same schema

  (i.e., `{(‘alice’, ‘lakers’), (‘alice’, (‘iPod’, ‘apple’)), (‘alice’, ‘lakers’)}`)
- **Map**: a collection of data items associated with a key

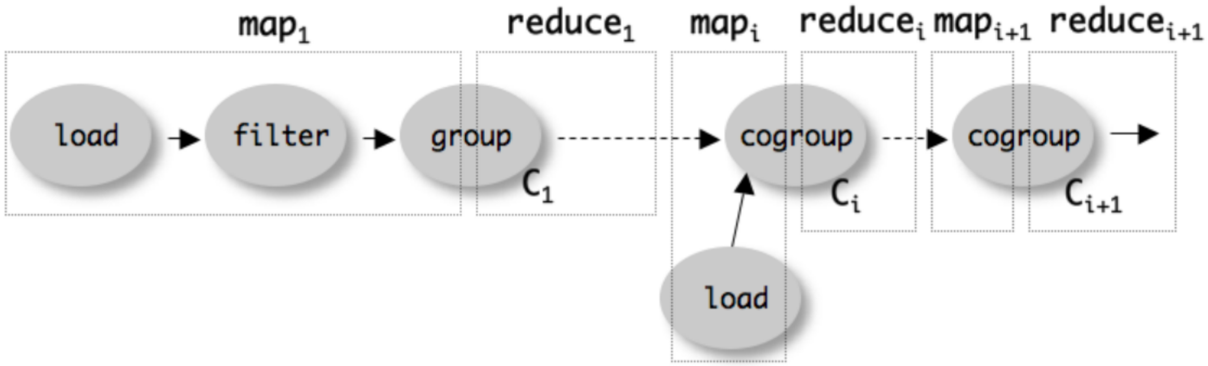
  (i.e., `[‘fanOf’->{(‘lakers’),(‘iPod’)} ‘age’ -> 20]`)

Implementation (1)

Implemented using Hadoop, by compiling Pig Latin into map-reduce jobs.

- The Pig Latin interpreter parses the input files and bags to verify the command is valid
- A *logical plan* (~ relational algebra) for every bag defined
- Execution is carried out only when `STORE` is invoked

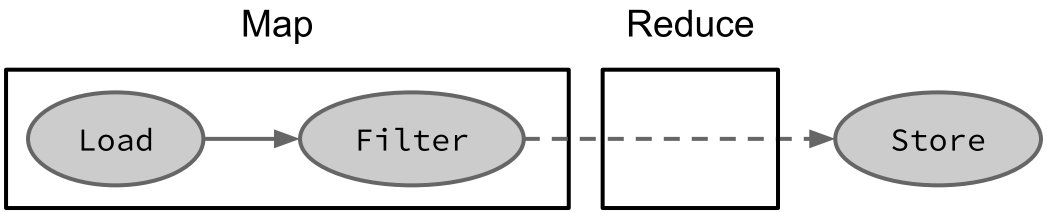
Implementation (2)



- Each COGROUP command is converted into a map-reduce job.
- The map function initially assigns key to tuples based on BY clauses.
- FILTER and FOREACH commands from the LOAD to the first COGROUP are pushed into the map of C_1.
- Subsequent commands (C_i) are pushed in the reduce functions of their corresponding COGROUP.

Grep - PigLatin

```
messages = LOAD 'messages'
warns = FILTER messages BY $0 MATCHES '.*WARN+.*'
STORE warns INTO 'warnings'
```



PigLatin vs MapReduce and Dryad

- No quantitative results
- PigLatin is much more focused on usability
  - Allows for User Defined Functions
  - It come together with a debugging environment

Questions?

References

Dean, Jeffrey, and Sanjay Ghemawat. "MapReduce: simplified data processing on large clusters." *Communications of the ACM* 51.1 (2008): 107-113.

Isard, Michael, et al. "Dryad: distributed data-parallel programs from sequential building blocks." *ACM SIGOPS Operating Systems Review*. Vol. 41. No. 3. ACM, 2007.

Olston, Christopher, et al. "Pig latin: a not-so-foreign language for data processing." *Proceedings of the 2008 ACM SIGMOD international conference on Management of data*. ACM, 2008.

Graph

- Dryad library is used to create a graph vertex.
- New edges are created by applying either pointwise or complete bipartite composition operation to two existing graphs.
- Users can also define new composition operations
- Graphs can also be merged

Job

- vertices are created according to partitioned input data.
- outputs are concatenated to produce a single named distributed file.
- Each vertex is placed into a stage to simplify job management.

Job Execution

- job manager tracks state and history of vertices
- job is terminated if job manager fails
- job manager performs greedy scheduling