Big data: architectures and data analytics
MapReduce patterns
Data Organization Patterns
Data Organization Patterns

- Are used to reorganize/split in subsets the input data
  - Binning
  - Shuffling
- The output of an application based on an organization pattern is usually the input of another application(s)
Data Organization Patterns

Binning
Goal
- Organize/move the input records into categories

Intent
- Partition a big data set into distinct, smaller data sets ("bins") containing similar records
  - Each partition is usually the input of a following analysis

Motivation
- The input data set contains heterogeneous data, but each data analysis usually is focused only on a specific subset of your data
Based on a Map-only job

Driver

- Sets the list of “bins/output files” by means of MultipleOutputs

Mappers

- For each input (key, value) pair, select the output bin/file associated with it and emit a (key, value) in that file
  - key of the emitted pair = key of the input pair
  - value of the emitted pair = value of the input pair

No combiner or reducer is used in this pattern
Binning - structure

(record_idX, recordX)
(record_idU, recordU)
(record_idY, recordY)
....

(record_idZ, recordZ)
(record_idW, recordW)
(record_idA, recordA)
....

....
....
....
....

Mapper

BIN1-m-0000
 BIN2-m-0000
   ...
 BINN-m-0000

Mapper

BIN1-m-0001
 BIN2-m-0001
   ...
 BINN-m-0001

Mapper
Data Organization Patterns

Shuffling
Goal
- Randomize the order of the data (records)

Motivation
- Randomize the order of the data
  - For anonymization reasons
  - For selecting a subset of random data (records)
Mappers

- Emit one (key, value) for each input record
  - key is a random key (i.e., a random number)
  - value is the input record

Reducers

- Emit one (key, value) pair for each value in [list-of-values] of the input (key, [list-of-values]) pair
Shuffling - structure

Mapper

Reducer

Mapper

Reducer

Mapper

(recent key, input record₁)
(recent key, input record₂)

...(input recordᵢᵣ, null)
...(input recordᵢᵦ, null)

...(offset, input record₁)
...(offset, input record₂)

....

...(offset, input recordᵢᵣ)
...(offset, input recordᵢᵦ)

....

....
Metapatterns
Metapatterns

- Are used to organize the workflow of a complex application executing many jobs
  - Job Chaining
Metapatterns

Job Chaining
Job Chaining

- **Goal**
  - Execute a sequence of jobs (synchronizing them)

- **Intent**
  - Manage the workflow of complex applications based on many phases (iterations)
    - Each phase is associated with a different MapReduce Job (i.e., one sub-application)
    - The output of a phase is the input of the next one

- **Motivation**
  - Real applications are usually based on many phases
Job Chaining - structure

- The (single) Driver
  - Contains the workflow of the application
  - Executes the jobs in the proper order
- Mappers, reducers, and combiners
  - Each phase of the complex application is implemented by a MapReduce Job
    - i.e., it is associated with a mapper, a reducer (and a combiner if it is useful)
Job Chaining - structure

Input data set → Job1 → Output Job1

Job2 → Output Job2

Jobn → Final output
More complex workflows, which execute jobs in parallel, can also be implemented.

However, the synchronization of the jobs become more complex.
Join Patterns
Join Patterns

- Are use to implement the join operators of the relational algebra (i.e., the join operators of traditional relational databases)
  - Reduce side join
  - Map side join
Join Patterns

- We will focus on the natural join
- However, the pattern is analogous for the other types of joins (theta-, semi-, outer-join)
Join Patterns

Reduce side natural join
Goal
- Join the content of two relations (i.e., relational tables)
  - Both tables are large

Motivation
- The join operation is useful in many applications
Reduce side natural join - structure

- There are two mapper classes
  - One mapper class for each table
- Mappers
  - Emit one (key, value) pair for each input record
    - Key is the value of the common attribute(s)
    - Value is the concatenation of the name of the table of the current record and the content of the current record
Suppose you want to join the following tables:

- Users with schema userid, name, surname
- Likes with schema userid, movieGenre

The record:

- userid=u1, name=Paolo, surname=Garza of the Users table will generate the pair
  - (userid=u1, “Users:name=Paolo,surname=Garza”)

While the record:

- userid=u1, movieGenre=horror of the Likes table will generate the pair
  - (userid=u1, “Likes:movieGenre=horror”)

Reduce side natural join - structure
Reducers

- Iterate over the values associated with each key (value of the common attributes) and compute the “local natural join” for the current key
  - Generate a copy for each pair of values such that one record is a record of the first table and the other is the record of the other table
For instance, the (key, [list of values]) pair

- (userid=u1, [“User:name=Paolo,surname=Garza”, “Likes:movieGenre=horror”, “Likes:movieGenre=adventure”]) will generate the following output (key,value) pairs
  - (userid=u1, “name=Paolo,surname=Garza, genre=horror”)
  - (userid=u1, “name=Paolo,surname=Garza, genre=adventure”)
Reduce side natural join - structure

Relation A (Table A)
(offset, recordA1)
(offset, recordA2)
(offset, recordA3)

Relation B (Table B)
(offset, recordB1)
(offset, recordB2)

Mapper A

Mapper A

Mapper B

Mapper B

Reducer

Reducer

(common attributes, table name + record)

(null, A_i join B_j)

(null, A_k join B_l)

(null, A_i join B_j)

(null, A_k join B_l)
Join Patterns

Map side natural join
Map side natural join

- Goal
  - Join the content of two relations (i.e., relational tables)
    - One table is large
    - The other is small enough to be loaded in main memory

- Motivation
  - The join operation is useful in many applications and frequently one of the two tables is small
Map side natural join - structure

- Map-only job
- One single mapper class
  - Processes the content of the large table
    - Receives one input (key, value) pair for each record of the large table
- The distributed cache approach is used to “provide” a copy of the small table to all mappers
Mappers

- Perform the “local natural join” between the current record (of the large table) and the records of the small table (that is in the distributed cache)
- The content of the small file is load in the main memory of the mapper during the execution of the setup method
Map side natural join - structure

Relation A (data set A)
(offset, recordA1)
(offset, recordA2)
(offset, recordA3)
....

Relation B (data set B)
(offset, recordB1)
(offset, recordB2)
....

Mapper A

(null, A_i join B_j)

(null, A_k join B_i)

....

Distributed cache
Join Patterns

Theta-join, Semi-join, Outer-join
The SQL language is characterized by many types of joins
- Theta-join
- Semi-join
- Outer-join

The same patterns used for implementing the natural join can be used also for the other SQL joins
- The “local join” in the reducer of the reduce side natural join (in the mapper of the map side natural join) is substituted with the type of join of interest (theta-, semi-, or outer-join)