Relational Algebra Operations and MapReduce

Relational Algebra Operators

- The relational algebra and the SQL language have many useful operators
  - Selection
  - Projection
  - Union, intersection, and difference
  - Join (see Join design patterns)
  - Aggregations and Group by (see the Summarization design patterns)

Relational Algebra Operators

- The MapReduce paradigm can be used to implement relational operators
  - However, the MapReduce implementation is efficient only when a full scan of the input table(s) is needed
    - i.e., when queries are not selective and process all data
  - Selective queries, which return few tuples/records of the input tables, are usually not efficient when implemented by using a MapReduce approach

Relational Algebra Operators

- Most preprocessing activities involve relational operators
  - E.g., ETL processes in the data warehousing application context

Relations/Tables

- Relations/Tables (also the big ones) can be stored in the HDFS distributed file system
  - They are broken in blocks and spread across the servers of the Hadoop cluster

Relations/Tables

- Note
  - In relational algebra, relations/tables do not contain duplicate records by definition
  - This constraint must be satisfied by both the input and the output relations/tables

Selection

- σ_C (R)
  - Applies predicate (condition) C to each record of table R
  - Produces a relation containing only the records that satisfy predicate C
- The selection operator can be implemented by using the filtering pattern

Selection

Courses

CCode	CName	Semester	ProfID
M2170	Computer science	1	D102
M4880	Digital systems	2	D104
F1401	Electronics	1	D104
F0410	Databases	2	D102

- Find the courses held in the second semester
- $\sigma_{Semester=2}$ (Courses)

Selection

Courses

CCode	CName	Semester	ProfID
M2170	Computer science	1	D102
M4880	*Digital systems*	*2*	*D104*
F1401	Electronics	1	D104
F0410	*Databases*	*2*	*D102*

Result

CCode	CName	Semester	ProfID
M4880	Digital systems	2	D104
F0410	Databases	2	D102

Selection

- Map-only job
- Each mapper
  - Analyzes one record at a time of its split
    - If the record satisfies C then it emits a (key,value) pair with key=record and value=null
    - Otherwise, it discards the record

Projection

- $\pi_S(R)$
  - For each record of table R, keeps only the attributes in S
  - Produces a relation with a schema equal to S (i.e., a relation containing only the attributes in S)
  - Removes duplicates, if any

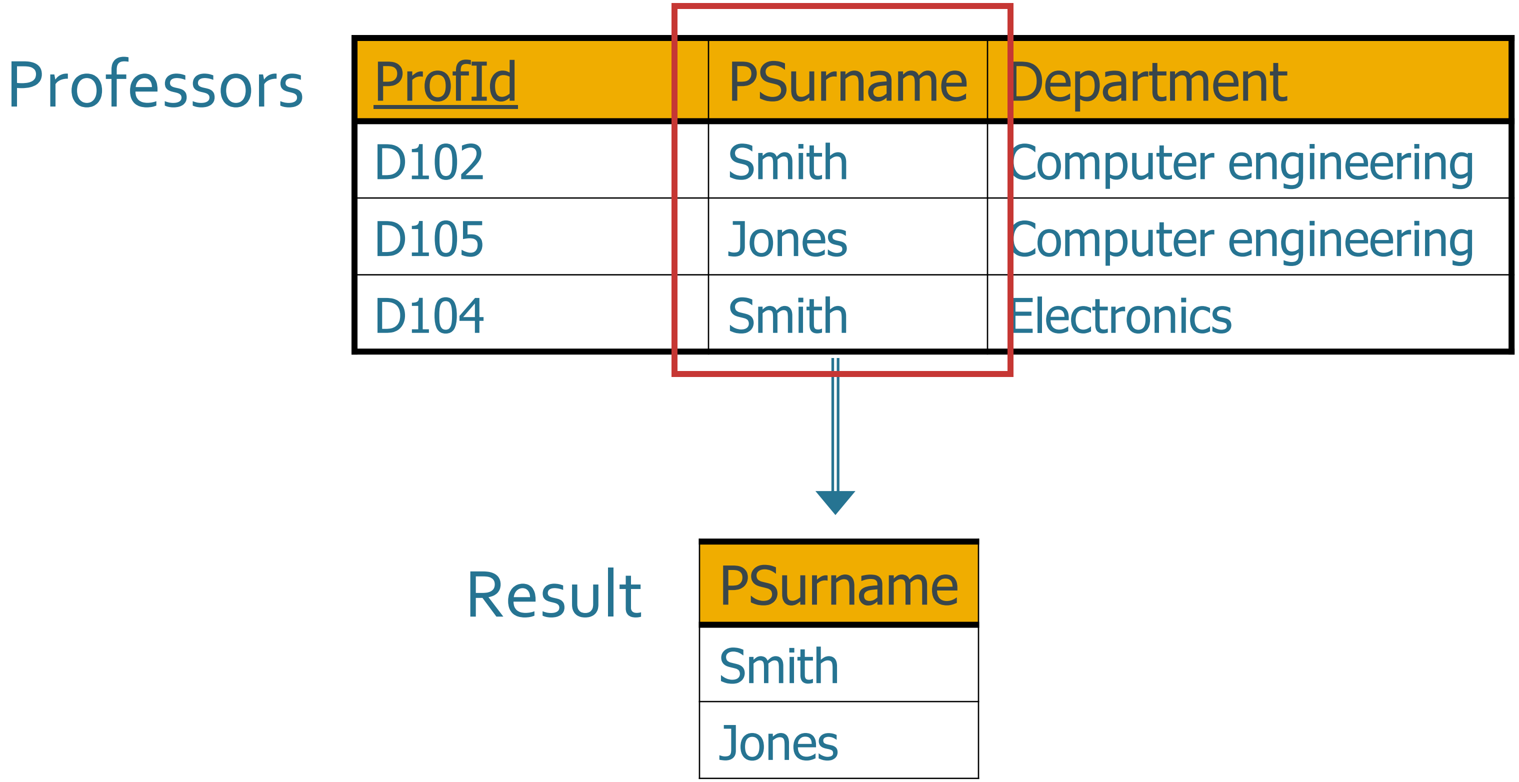
Projection

Professors

ProfId	PSurname	Department
D102	Smith	Computer engineering
D105	Jones	Computer engineering
D104	Smith	Electronics

- Find the surnames of all professors
- π_{PSurname}(Professors)

Projection



Professors

ProfId	PSurname	Department
D102	Smith	Computer engineering
D105	Jones	Computer engineering
D104	Smith	Electronics

Result

PSurname
Smith
Jones

- Duplicated values are removed

Projection

- Each mapper
  - Analyzes one record at a time of its split
    - For each record r in R
      - It selects the values of the attributes in S and constructs a new record r’
      - It emits a (key,value) pair with key=r’ and value=null
- Each reducer
  - Emits one (key, value) pair for each input (key, [list of values]) pair with key=r’ and value=null

Union

- $R \cup S$
  - R and S have the same schema
  - Produces a relation with the same schema of R and S
  - There is a record t in the output of the union operator for each record t appearing in R or S
  - Duplicated records are removed

Union

DegreeCourseProf

ProfID	PSurname	Department
D102	Smith	Computer engineering
D105	Jones	Computer engineering
D104	White	Electronics

MasterCourseProf

ProfID	PSurname	Department
D102	Smith	Computer engineering
D101	Red	Electronics

- Find information relative to the professors of degree courses or master’s degrees
- DegreeCourseProf $\cup$ MasterCourseProf

Union

DegreeCourseProf

<u>ProfID</u>	PSurname	Department
D102	Smith	Computer engineering
D105	Jones	Computer engineering
D104	White	Electronics

MasterCourseProf

<u>ProfID</u>	PSurname	Department
D102	Smith	Computer engineering
D101	Red	Electronics

→

Result

<u>ProfID</u>	PSurname	Department
D102	Smith	Computer engineering
D105	Jones	Computer engineering
D104	White	Electronics
D101	Red	Electronics

Union

- Mappers
  - For each input record t in R, emit one (key, value) pair with key=t and value=null
  - For each input record t in S, emit one (key, value) pair with key=t and value=null
- Reducers
  - Emit one (key, value) pair for each input (key, [list of values]) pair with key=t and value=null
    - i.e., one single copy of each input record is emitted

Intersection

- $R \cap S$
  - R and S have the same schema
  - Produces a relation with the same schema of R and S
  - There is a record t in the output of the intersection operator if and only if t appears in both relations (R and S)

Intersection

DegreeCourseProf

ProfID	PSurname	Department
D102	Smith	Computer engineering
D105	Jones	Computer engineering
D104	White	Electronics

MasterCourseProf

ProfID	PSurname	Department
D102	Smith	Computer engineering
D101	Red	Electronics

- Find information relative to professors teaching both degree courses and master’s courses
- DegreeCourseProf ∩ MasterCourseProf

Intersection

DegreeCourseProf

ProfID	PSurname	Department
D102	Smith	Computer engineering
D105	Jones	Computer engineering
D104	White	Electronics

MasterCourseProf

ProfID	PSurname	Department
D102	Smith	Computer engineering
D101	Red	Electronics

Result

ProfID	PSurname	Department
D102	Smith	Computer engineering

Intersection

- Mappers
  - For each input record t in R, emit one (key, value) pair with key=t and value="R"
  - For each input record t in S, emit one (key, value) pair with key=t and value="S"

Intersection

- Reducers
  - Emit one (key, value) pair with key=t and value=null for each input (key, [list of values]) pair with [list of values] containing two values
    - It happens if and only if both R and S contain t

Difference

- R - S
  - R and S have the same schema
  - Produces a relation with the same schema of R and S
  - There is a record t in the output of the difference operator if and only if t appears in R but not in S

Difference

DegreeCourseProf

ProfID	PSurname	Department
D102	Smith	Computer engineering
D105	Jones	Computer engineering
D104	White	Electronics

MasterCourseProf

ProfID	PSurname	Department
D102	Smith	Computer engineering
D101	Red	Electronics

- Find the professors teaching degree courses but not master’s courses
- DegreeCourseProf - MasterCourseProf

Difference

DegreeCourseProf

ProfID	PSurname	Department
D102	Smith	Computer engineering
D105	Jones	Computer engineering
D104	White	Electronics

MasterCourseProf

ProfID	PSurname	Department
D102	Smith	Computer engineering
D101	Red	Electronics

Result

ProfID	PSurname	Department
D105	Jones	Computer engineering
D104	White	Electronics

Difference

- Mappers
  - For each input record t in R, emit one (key, value) pair with key=t and value=name of the relation (i.e., R)
  - For each input record t in S, emit one (key, value) pair with key=t and value=name of the relation (i.e., S)
- Two mapper classes are needed
  - One for each relation

Difference

- Reducers
  - Emit one (key, value) pair with key=t and value=null for each input (key, [list of values]) pair with [list of values] containing only the value R
    - It happens if and only if t appears in R but not in S

Join

- The join operators can be implemented by using the Join pattern
  - By using the reduce side or the map side pattern depending on the size of the input relations/tables

Aggregations and Group by

- Aggregations and Group by are implemented by using the Summarization pattern