Spark SQL

Architecture and Data Structures

Pietro Michiardi

Eurecom

- M. Aembrust, et. al., “Spark SQL: Relational Data Processing in Spark”, in Proc. of ACM Sigmod 2015
- Lookup for slides on SlideShare, and videos around the web!

Introduction

Introduction

- **High-level programming language: SQL**
  - Expressiveness, succinctness
  - Enables compatibility with existing tools, e.g. BI using JDBC
  - Large pool of engineers proficient in SQL

- **Project goals**
  - Write less code
  - Read less data
  - Let the optimizer do the hard work

- **Design philosophy**
  - SparkSQL is a Library
  - Uses the SparkContext to interact with Spark

Challenges

- **Variety of data source formats**
  - ETL workloads often involve working with various kinds of data

  $\rightarrow$ DataSource API

- **SQL implementation**
  - Extensibility, e.g. to cover SQL standard

  $\rightarrow$ DataFrame API

  - Efficiency

  $\rightarrow$ Catalyst optimizer

Outline

- **Spark and SparkSQL data structures**
- **Functional architecture, with a RDBMS flavor**
- **Performance**

Data Representation

DataSource API

- **Read and write with a variety of formats**

DataSource API

- Unified interface to reading data
- read function creates new I/O builders
- load function creates new I/O builders

```
df = sqlContext.read \
  .format(''json'') \
  .option(''samplingRatio'', ''0.1'') \
  .load(''data.json'')
```

DataSource API

- Unified interface to writing data
- Write function creates new I/O builders
- save function creates new I/O builders

```
df.write \
   .format(''parquet'') \
   .mode(''append'') \
   .partitionBy(''year'') \
   .saveAsTable(''myData'')
```

DataSource API

- **Builder methods**
  - Specify data format
  - Define data partitioning
  - Handle existing data
  - ... and much more

DataFrame

- **Schema to the rescue**
  - A distributed collection of rows organized into named columns
  - Schema inference can be automatic
- **Structured data**
  - An abstraction for selecting, filtering, aggregating and plotting structured data

DataFrame

- **General idea borrowed from Python Pandas**
  - Tabular data with an API
  - Math, stats, algebra, ...
- **Relation to a low-level RDD**
  - Introduces structure to the data
  - Specific relational operators
    - Select required columns
    - Join different data sources
    - Aggregation operations
    - Filtering

DataFrame API

- Example using RDDs

```
data = sc.textFile(...).split('' '')
data.map(lambda x: (x[0], [int(x[1]), 1])) \
  .reduceByKey(lambda x, y: [x[0] + y[0], x[1] + y[1]]) \
  .map(lambda x: [x[0], x[1][0] / x[1][1]]) \
  .collect()
```

DataFrame API

- Example using SQL

```sql
SELECT name, avg(age)
FROM people
GROUP BY name
```

DataFrame API

- Example using DataFrames

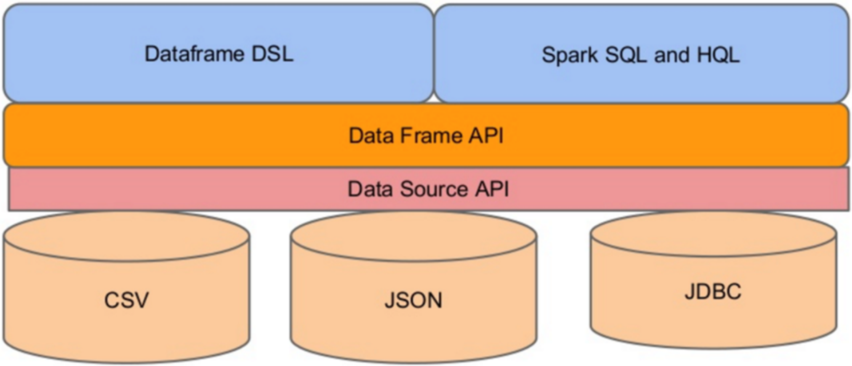
```
sqlContext.table(''people'') \
  .groupBy(''name'') \
  .agg(''name'', avg(''age'')) \
  .collect()
```

Architecture

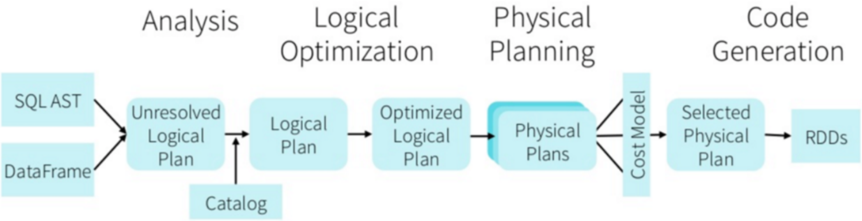
Background and roadmap

- **Reminiscent of traditional database systems**
  - Abstract representation of SQL expressions
  - Optimizations for efficiency and performance
  - Sophisticated cost model
- **Focus on optimizations**
  - Logical plan
  - Physical plan
  - Cost-based vs. Rule-based

Global view


Dataframe DSL
Spark SQL and HQL
Data Frame API
Data Source API
CSV
JSON
JDBC

SparkSQLContext

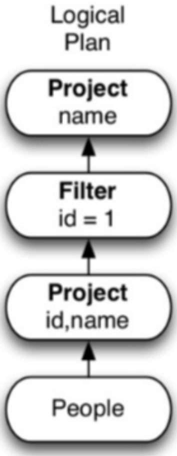


Catalyst optimizer

- **Overall goals**
  - Optimize logical plan
  - Convert logical to physical plan
  - Optimize physical plan
  - Code generation
- **Explot `scala` language features**
  - `Quasiquotes`
  - Abstract syntax tree
  - Tree manipulation library
  - Optimizations rules implemented as tree transformations

Example query

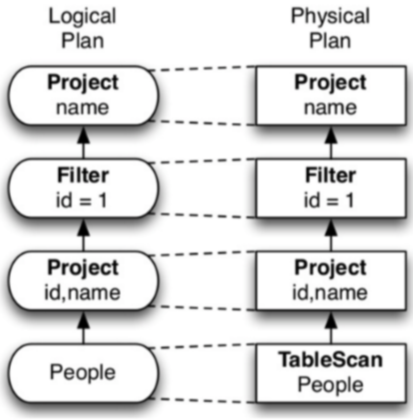
```
SELECT name
FROM (
        SELECT id, name
        FROM People) p
WHERE p.id = 1
```



Example query

Native query planning

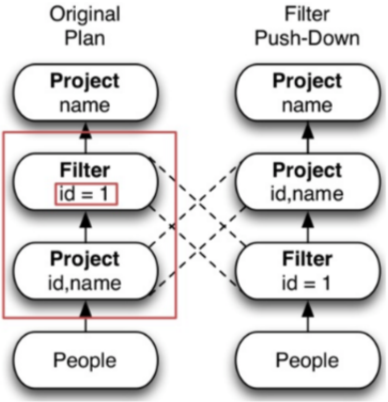
```
SELECT name
FROM (
        SELECT id, name
        FROM People) p
WHERE p.id = 1
```



Example query

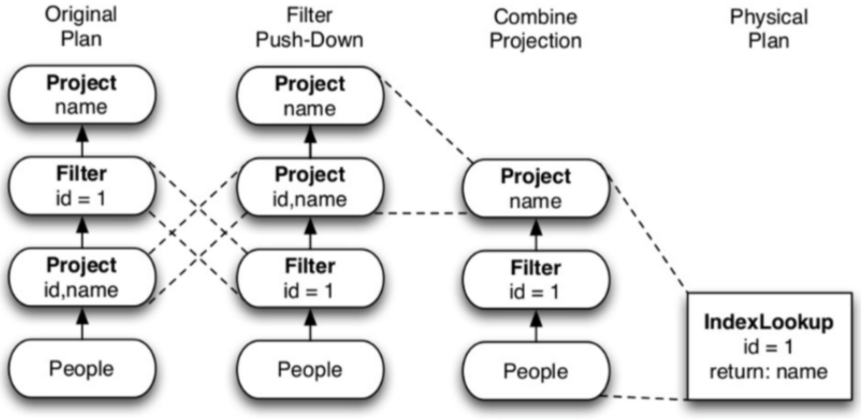
Optimization rules example

- Find filters on top of projections
- Check that filters can be evaluated without the result of the projection
- If yes, switch operators



Example query

- Definition of custom rules



Example Optimization Rules

- Eliminate subqueries
- Constant folding
- Simplify filters
- PushPredicate through filter
- Project collapsing

Project Tungsten

- **Runtime code generation**
  - Using code generation to exploit modern compilers and CPUs
- **Cache locality**
  - Algorithms and data structures to exploit memory hierarchy
- **Off-heap memory management**
  - Leveraging application semantics to manage memory explicitly and eliminate the overhead of JVM object model and garbage collection

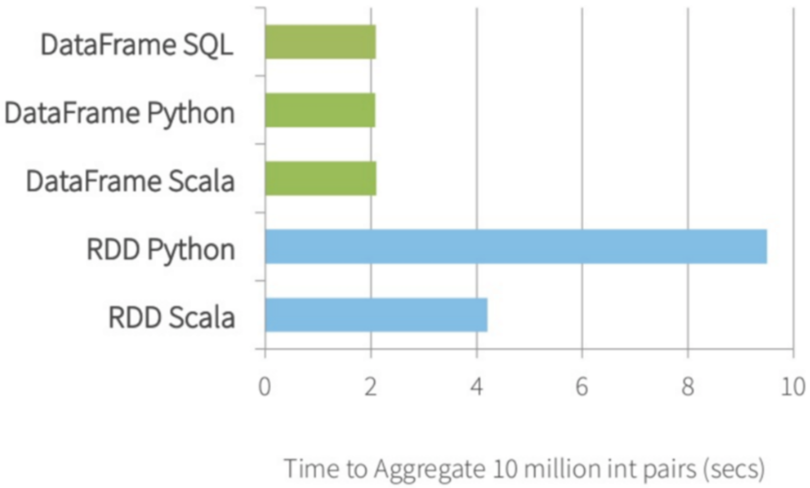
Advanced features

- Consider string "`abcd`"

```
java.lang.String object internals:
OFFSET  SIZE   TYPE DESCRIPTION                    VALUE
     0     4        (object header)                ...
     4     4        (object header)                ...
     8     4        (object header)                ...
    12     4 char[] String.value                   []
    16     4    int String.hash                    0
    20     4    int String.hash32                  0
Instance size: 24 bytes (reported by Instrumentation API)
```

Performance

Performance comparisons



Conclusion