Apache Spark* SQL expression evaluation

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Agenda

- Expression, UDF, UDAF & UDTF
- API definition
- Optimization in planning stage
- Code generation: part of Project Tungsten*
- Hivemall*: ML tools based on Hive UDF/UDAF/UDTF
- Future plan: vectorization

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Expression, UDF, UDAF & UDTF

- Expression(built-in function) represents a part of a structured query
  - Add(+), Coalesce, EqualTo(=), GreaterThan(>), Lower, Factorial, CurrentTimestamp(now)
  - Average, Count, Max (aggregate expression)

```
SELECT average(age) FROM test WHERE company=‘intel’
```

  - Explode (generator)

```
SELECT explode(array(10, 20)) ->
 10
 20
```

- UDF(user defined function): a feature of Spark SQL* to define new column-based functions that extend the vocabulary of Spark SQL
  - UDAF(user defined aggregate function)
  - UDTF(user defined table function)

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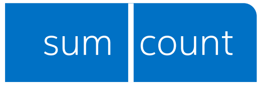
API definition -- Expression

```
abstract class Expression {
  def foldable: Boolean = false
  def nullable: Boolean
  def eval: Any
  def genCode: ExprCode
  …
}
```

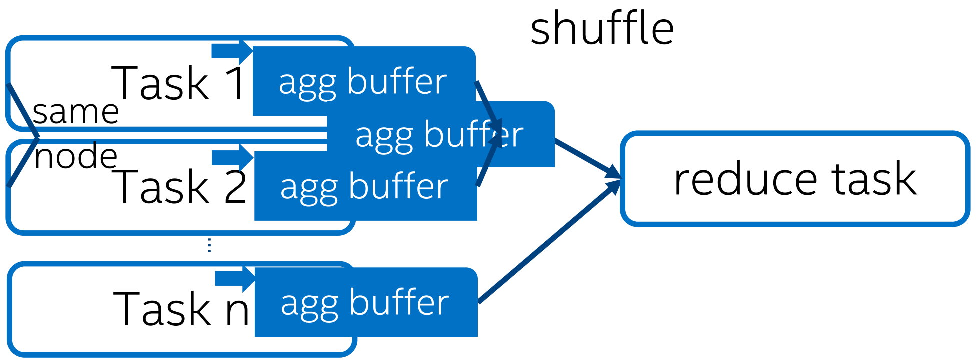
Add(1, 1)	Add(col1, col2)
true	false
false	col1.nullable || col2.nullable

```
case class Add(left: Expression, right: Expression) extends BinaryArithmetic {
  private lazy val numeric = TypeUtils.getNumeric(dataType)
  protected override def nullSafeEval(input1: Any, input2: Any): Any = {
    if (dataType.isInstanceOf[CalendarIntervalType]) {
      input1.asInstanceOf[CalendarInterval].add(input2.asInstanceOf[CalendarInterval])
    } else {
      numeric.plus(input1, input2)
    }
  }
  …
}
```

API definition -- Aggregate Expression



aggregation buffer for average



aggregate without groupby

- Core API :
  - **Initialize** a new buffer
  - **Update** the buffer with a row
  - **Merge** 2 buffers together
  - **Evaluate** final result with the buffer

```
case class Average(child: Expression) extends DeclarativeAggregate {
  override lazy val initialValues = Seq(
          Literal(0),
          Literal(0)
  )
  override lazy val updateExpressions = Seq(
          Add(sum, child),
          If(IsNull(child), count, count + 1L)
  )
  override lazy val mergeExpressions = Seq(
          sum.left + sum.right,
          count.left + count.right
  override lazy val evaluateExpression = sum / count
  ...
}
```

API definition – Easier way to write & register UDF & UDAF

- Register UDF:

```
sqlContext.udf.register("strLen", (s: String) => s.length())
```

- Register UDAF:

```
class MyAggregate extends UserDefinedAggregateFunction {
    …
}
sqlContext.udf.register(“my_aggregate", new MyAggregate )
```

- Pros: easier to implement compared to extending Expressions
- Cons: black box for Spark hence no optimization

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Optimization in planning stage

- Rules in analysis stage: PromoteStrings, **ImplicitTypeCasts**, DateTimeOperations, …
- Rules in optimization stage: **ConstantFolding**, PushDownPredicate, LikeSimplification, …

```
case class Concat(left: Expression, right: Expression) {
override def inputTypes: Seq[AbstractDataType] = Seq.fill(children.size)(StringType)
…
}
```

- concat example: *SELECT concat(“Spark”, “SQL”) => “SparkSQL”*
- *SELECT concat(framework, version) from version_statistics*

id	framework	version
1	“Spark”	2.1
2	“Flink”	1.2
3	“Hadoop”	2.7

```
def implicitCast(e: Expression, expectedType: AbstractDataType): Option[Expression] = {
    val ret: Expression = (e.datatype, expectedType) match {
        case (any: AtomicType, StringType) if any != StringType => Cast(e, StringType)
    …
    }
}
```

Optimization in planning stage

- Constant Folding in optimization stage

```
abstract class Expression {
  def foldable: Boolean = false
  …
}
```

```
case class Add(left: Expression, right: Expression) {
override def foldable: Boolean = left.foldable && right.foldable
…
}
```

- Add(1,1) -> Add(Literal(1), Literal(1))
- Literal(1).foldable = true
- Add(1,1).foldable = true

➡ Add(1,1) -> 2

```
object ConstantFolding extends Rule[LogicalPlan] {
  def apply(plan: LogicalPlan): LogicalPlan = plan transform {
     case q: LogicalPlan => q transformExpressionsDown {
       case l: Literal => l
       case e if e.foldable => Literal.create(e.eval(EmptyRow), e.dataType)
     }
  }
  …
}
```

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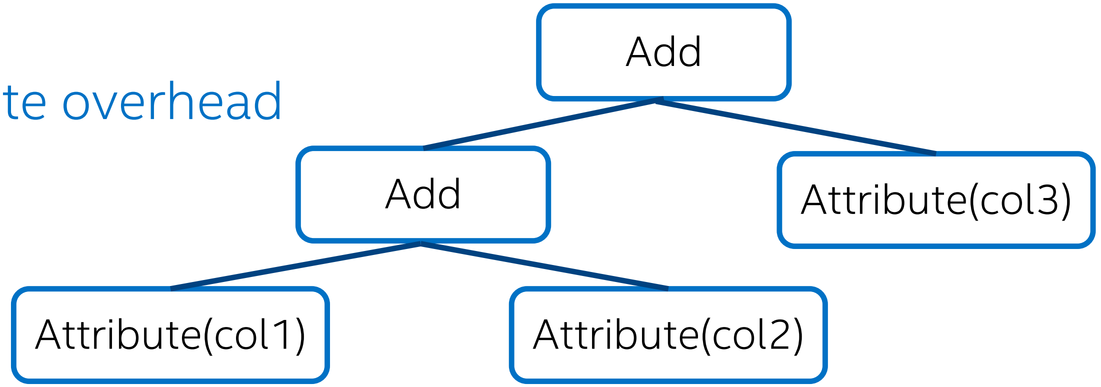
Code generation: part of Project Tungsten*

- Code generation:
  - Collapse multiple expressions into one to eliminate overhead

```
abstract class Expression {
  def genCode: ExprCode
  …
}
```



Evaluate col1+col2+col3 from leaf to root if without codegen

- Project Tungsten*:
  - Hardware offers increasingly large network & disk IO bandwith
  - Main focus: better efficiency of memory & CPU
  - *Also includes memory management & cache-aware computation besides codegen*

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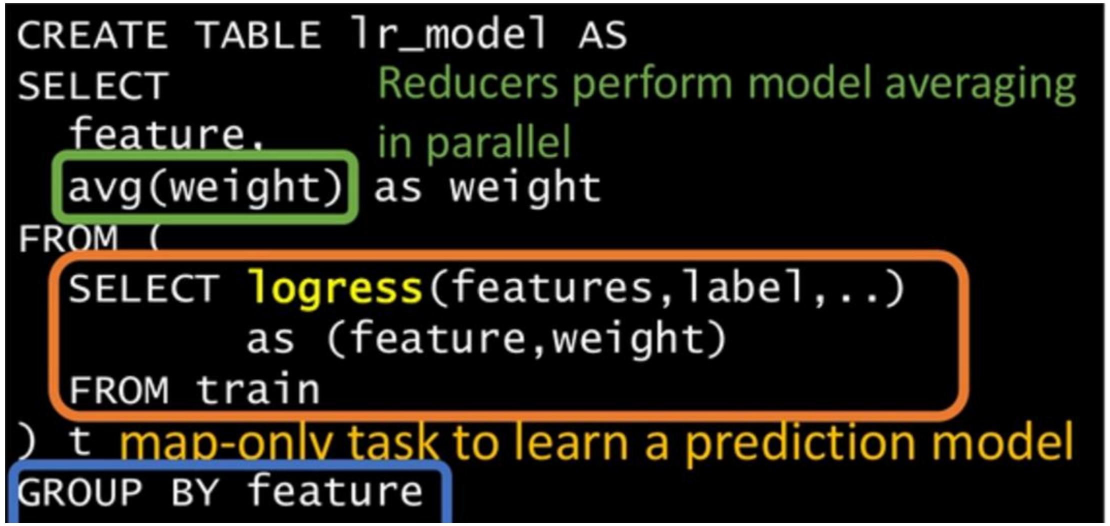
Hivemall*: ML tools based on Hive UDF/UDAF/UDTF

- Machine learning on SQL
- Supports Hive, Spark, Pig
- Apache Incubator project



```
CREATE TABLE lr_model AS
SELECT
  feature,
  avg(weight) as weight
FROM (
  SELECT logress(features,label,..)
         as (feature,weight)
  FROM train
) t
GROUP BY feature
```

Reducers perform model averaging in parallel
map-only task to learn a prediction model

Image from https://github.com/apache/incubator-hivemall

- Other state-of-the-art machine learning algorithms: Soft Confidence Weighted, Adaptive Regularization of Weight Vectors, Factorization Machines, and AdaDelta

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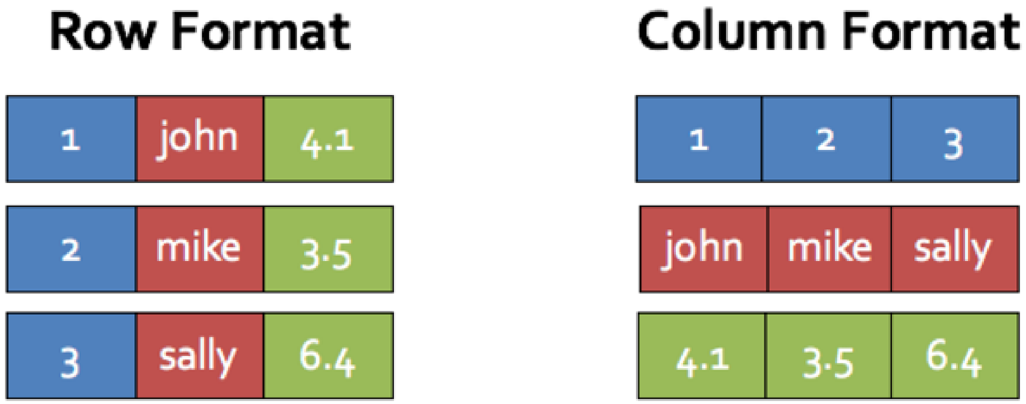
- # Future plan: vectorization

- Now: process data one row at a time
- One possible future: batch multiple rows together in a columnar format
- Already implemented: vectorized Parquet reader that does decompression and decoding in column batches

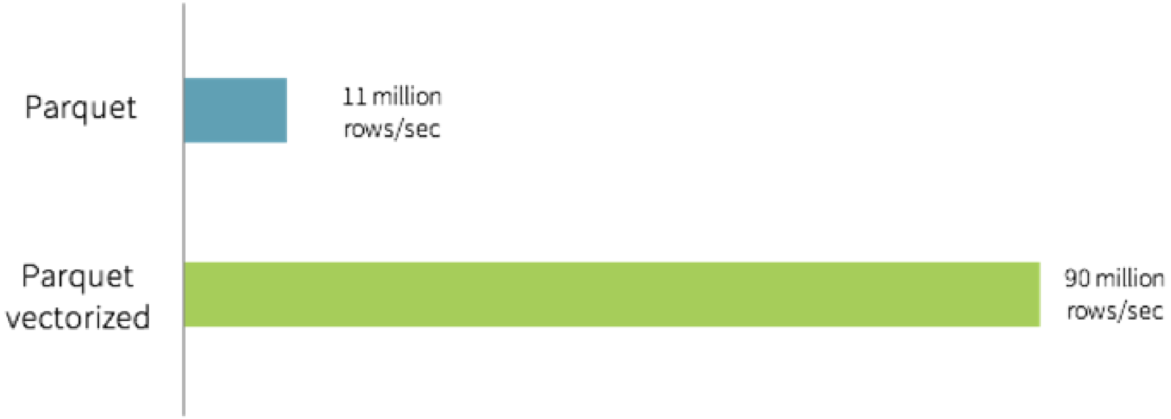


Row Format

1	john	4.1
2	mike	3.5
3	sally	6.4

Column Format

1	2	3
john	mike	sally
4.1	3.5	6.4



Benchmark from Databricks *

For more complete information about performance and benchmark results, visit www.intel.com/benchmarks *Other names and brands may be claimed as the property of others

- Q & A

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