Peeking into the Optimization of Data Flow Programs with MapReduce-style UDFs

StratoSphere
Above the Clouds

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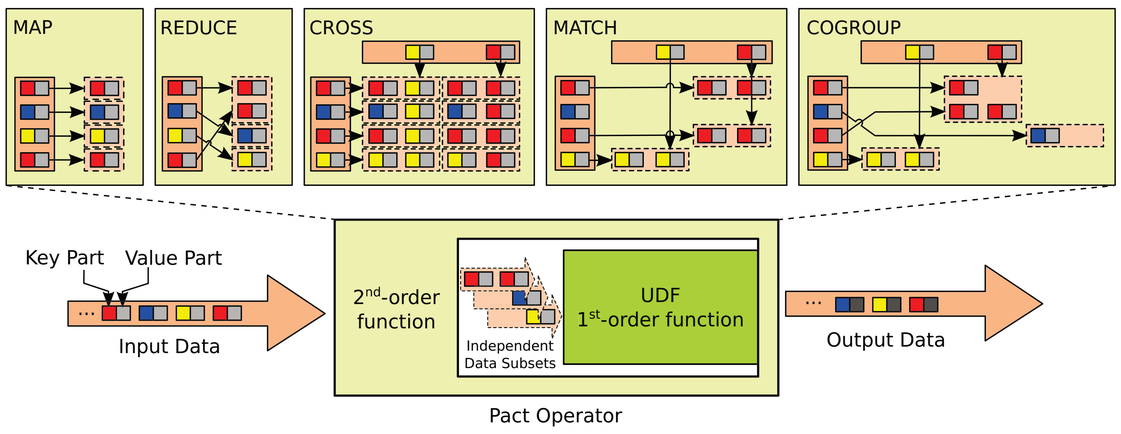
Motivation: Operator Reordering

- Data flow programming is a popular abstraction for complex analytics
- Diversity of data and tasks requires user-defined functions
- Operator order has significant impact on execution performance
- Reordering UDF operators requires knowlegde of UDF properties

Context: Pact Programming Model

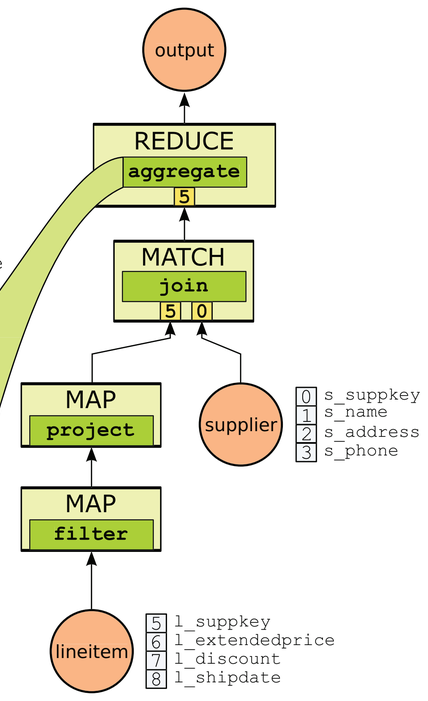


TPC-H Query 15 as PACT Program

```
CREATE VIEW revenue (supplier_no, total_revenue) AS
SELECT l_suppkey, SUM(l_extendedprice * (1 - l_discount))
  FROM lineitem
  WHERE
    l_shipdate >= 'DATE' AND
    l_shipdate < DATE 'DATE' + INTERVAL '3' MONTH
  GROUP BY l_suppkey;

SELECT s_suppkey, s_name, s_address, s_phone, total_revenue
  FROM supplier, revenue
  WHERE s_suppkey = supplier_no;
```

```
public void reduce(Iterator<PactRecord> records,
                   Collector out) {
  PactRecord resultRecord = records.next();
  double sum = resultRecord.getField(4);
  while (records.hasNext()) {
   resultRecord = records.next();
   sum += resultRecord.getField(4);
  }
  resultRecord.setField(4, sum);
  out.collect(resultRecord);
}
```



UDF Code Analysis

Prerequisites:

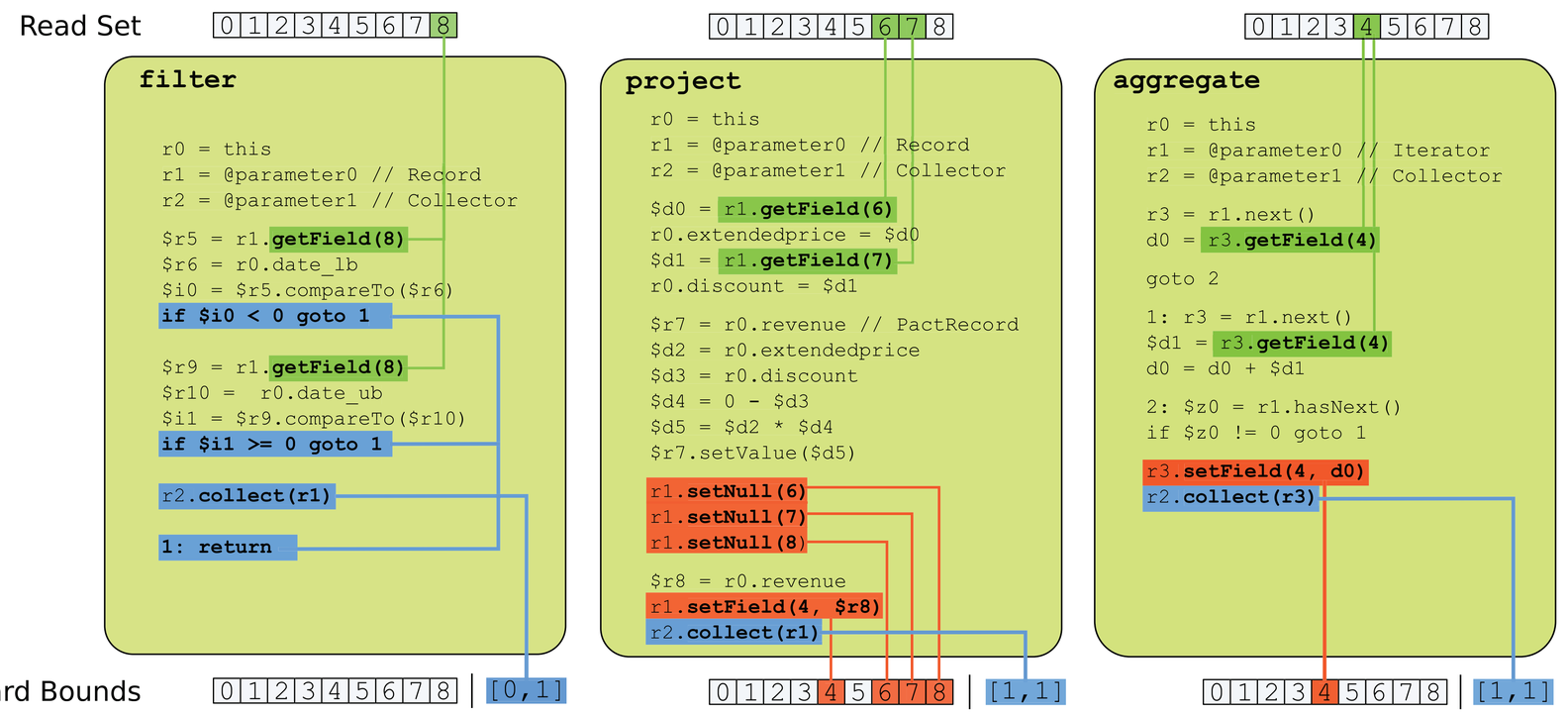
- Static Code Analysis Framework provides
  Control-Flow, Def-Use, Use-Def lists
- Fixed API to access records

Extracted Information:

- Field sets track read and write accesses on records
- Upper and lower output cardinality bounds

Safety:

- All record access instructions are detected
- Supersets of actual Read/Write sets are returned
- Supersets allow fewer but always safe transformations



Details in [HPS+12] and [HKT12]

Data Flow Transformations

Reorder Conditions:

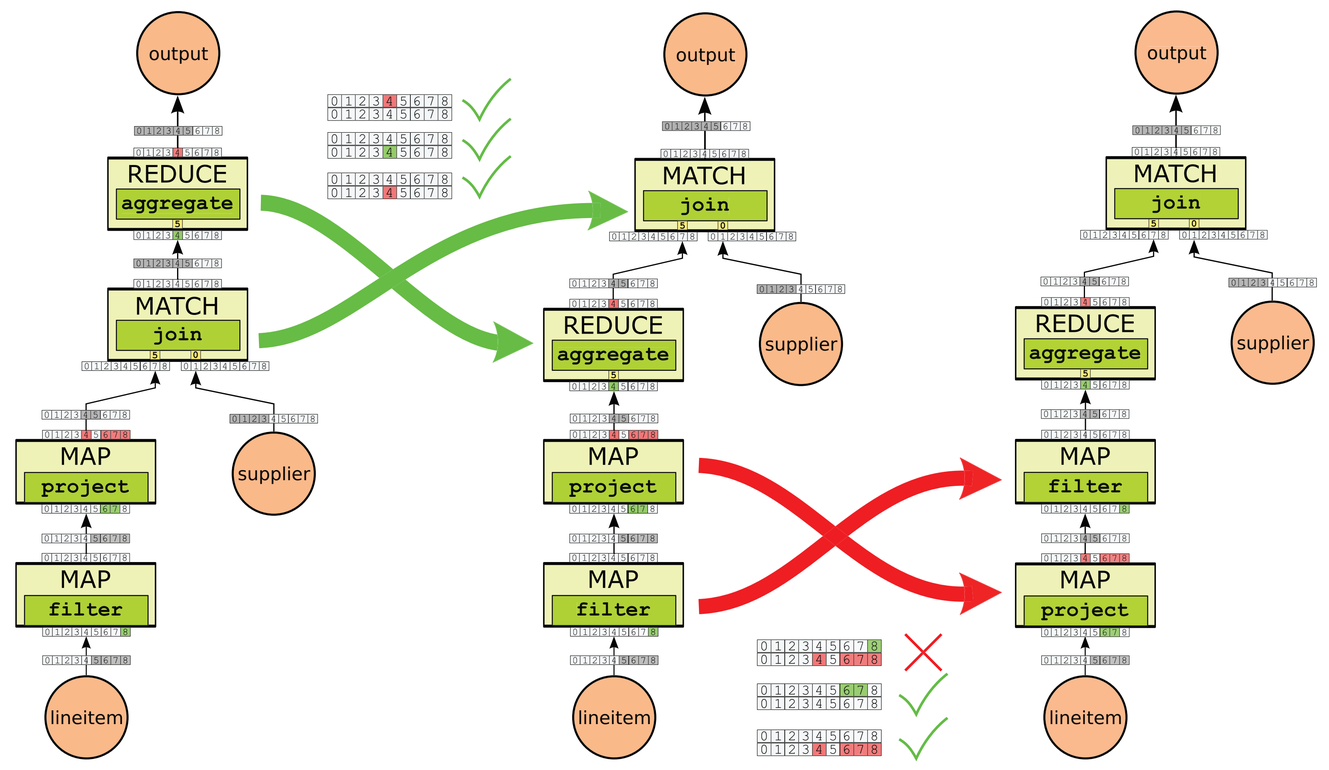
1. No Write-Read / Write-Write conflicts on record fields
   - Similar to conflict detection in optimistic concurrency control
2. Preservation of groups for grouping operators
   - Groups must remain unchanged or be completely removed

Enumeration Algorithm:

- Descents data flow recursively top-down
- Checks reorder conditions and switches successive operators

Supported Transformations:

- Filter push-down
- Join reordering
- Invariant group transformations
- Non-relational operators are integrated



Details in [HPS+12]

Physical Optimization

Execution Plan Selection:

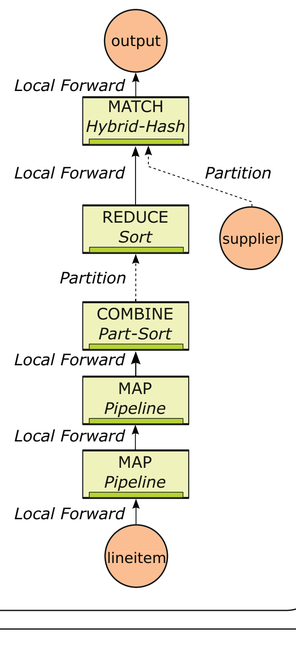
- Chooses execution strategies for 2nd-order functions
- Chooses shipping strategies to distribute data
- Strategies known from parallel databases

Interesting Properties:

- Sorting, Grouping, Partitioning
- Property preservation reasoning with write sets

Cost-based Plan Selection:

- Exploits UDF annotations for size estimates
- Cost model combines network, disk I/O and CPU costs



Details in [BEH+10]

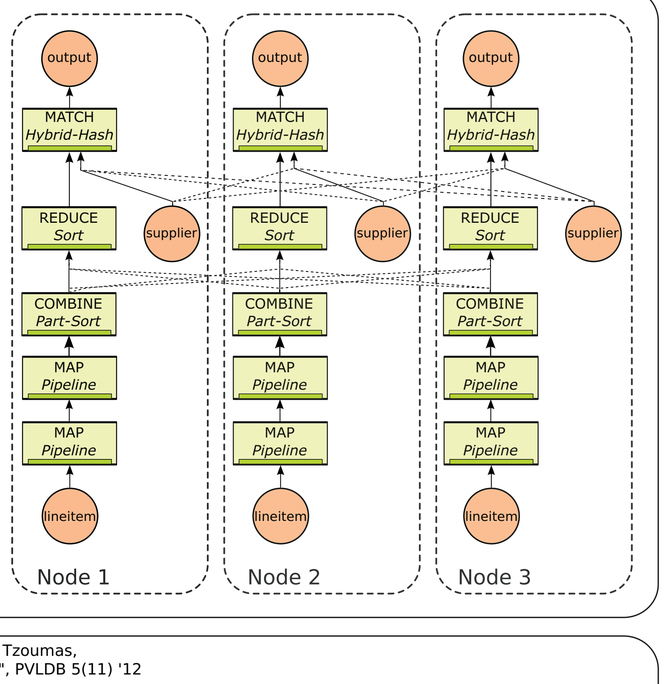
Parallel Execution

Execution Engine:

- Massively parallel execution of DAG-structured data flows
- Sequential processing tasks
- Synchronous communication (In-memory and network)

Runtime Operators:

- Implemented as sequential processing tasks
- Call UDFs



Details in [BEH+10] and [WK09]

[WK09] Warneke, Kao,
"Nephele: Efficient Parallel Data Processing in the Cloud", MTAGS '09

[BEH+10] Battré, Ewen, Hueske, Kao, Markl, Warneke,
"Nephele/PACTs: A Programming Model and Execution Framework for Web-Scale Analytical Processing", SOCC '10

[HPS+12] Hueske, Peters, Sax, Rheinländer, Bergmann, Krettek, Tzoumas,
"Opening the Black Boxes in Data Flow Optimization", PVLDB 5(11) '12

[HKT12] Hueske, Krettek, Tzoumas,
"Enabling Operator Reordering in Data Flow Programs Through Static Code Analysis", XLDI Workshop '12

Stratosphere
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