How to Win a Hot Dog Eating Contest: Incremental View Maintenance with Batch Updates

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REALTIME APPLICATIONS

Web Analytics

Sensor Networks

Cloud Monitoring

EVENTS → RUNTIME ENGINE → DECISION SUPPORT → ACTIONS

Continuously arriving data

Continuously evaluated views

REALTIME SYSTEMS: REQUIREMENTS

LOW LATENCY PROCESSING

Incremental view maintenance

$Q(D + \Delta D) = Q(D) + \Delta Q(D, \Delta D)$

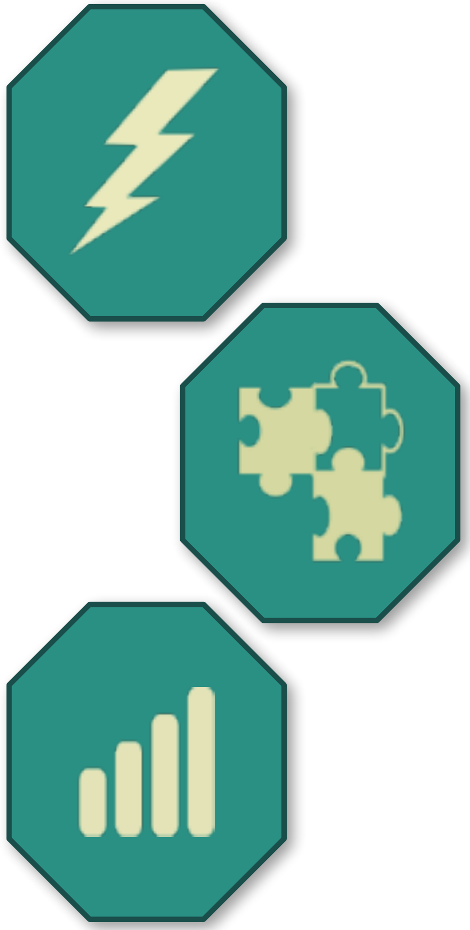
COMPLEX CONTINUOUS QUERIES

SQL queries (w/ nested aggregates)

No window semantics

SCALABLE PROCESSING

Synchronous execution model



IN THIS TALK

Q1: How does the size of update affect the performance of incremental computation?

Q2: (Idea) How to achieve efficient distributed incremental computation?

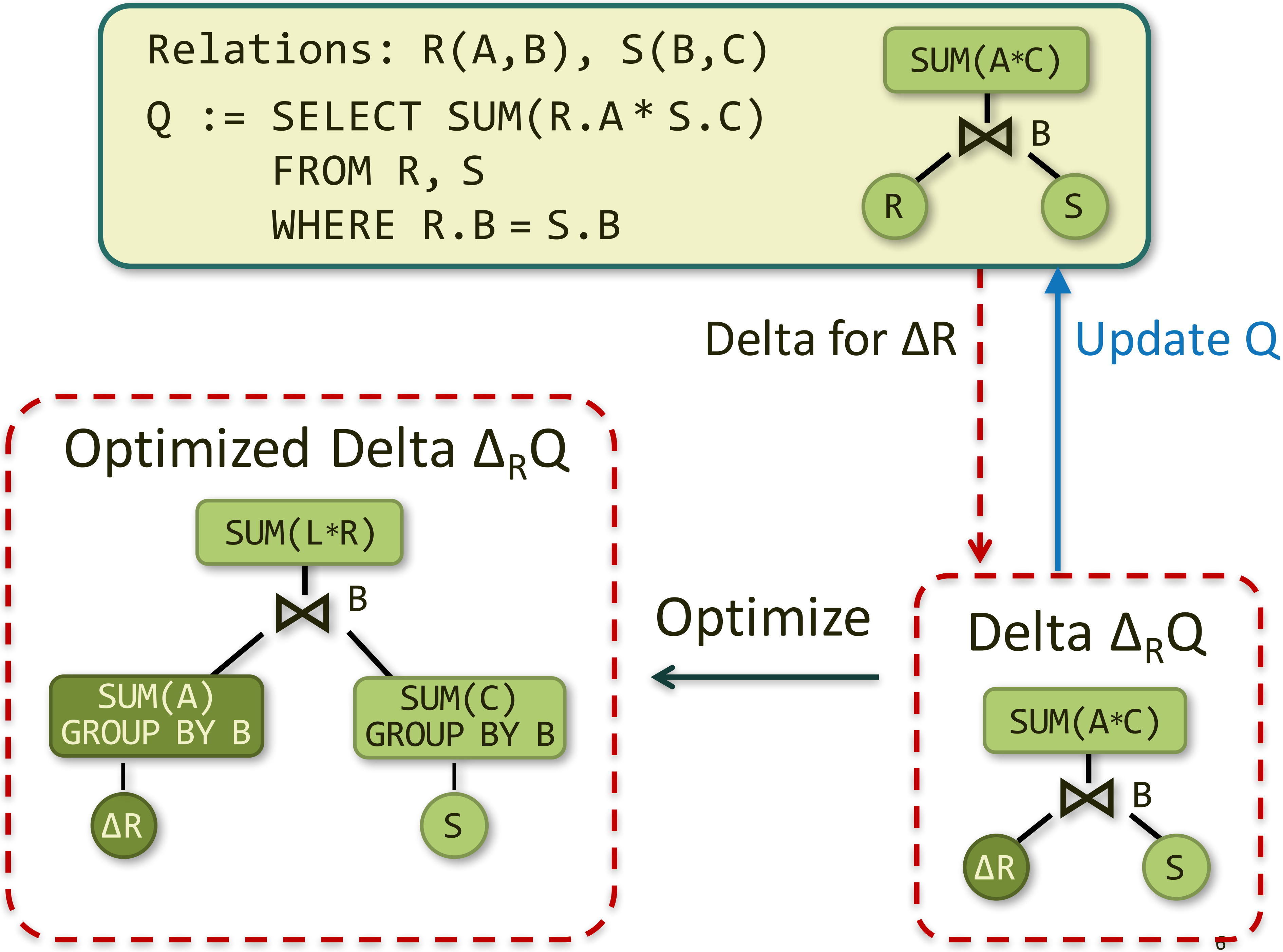
HIGH-PERFORMANCE INCREMENTAL COMPUTATION

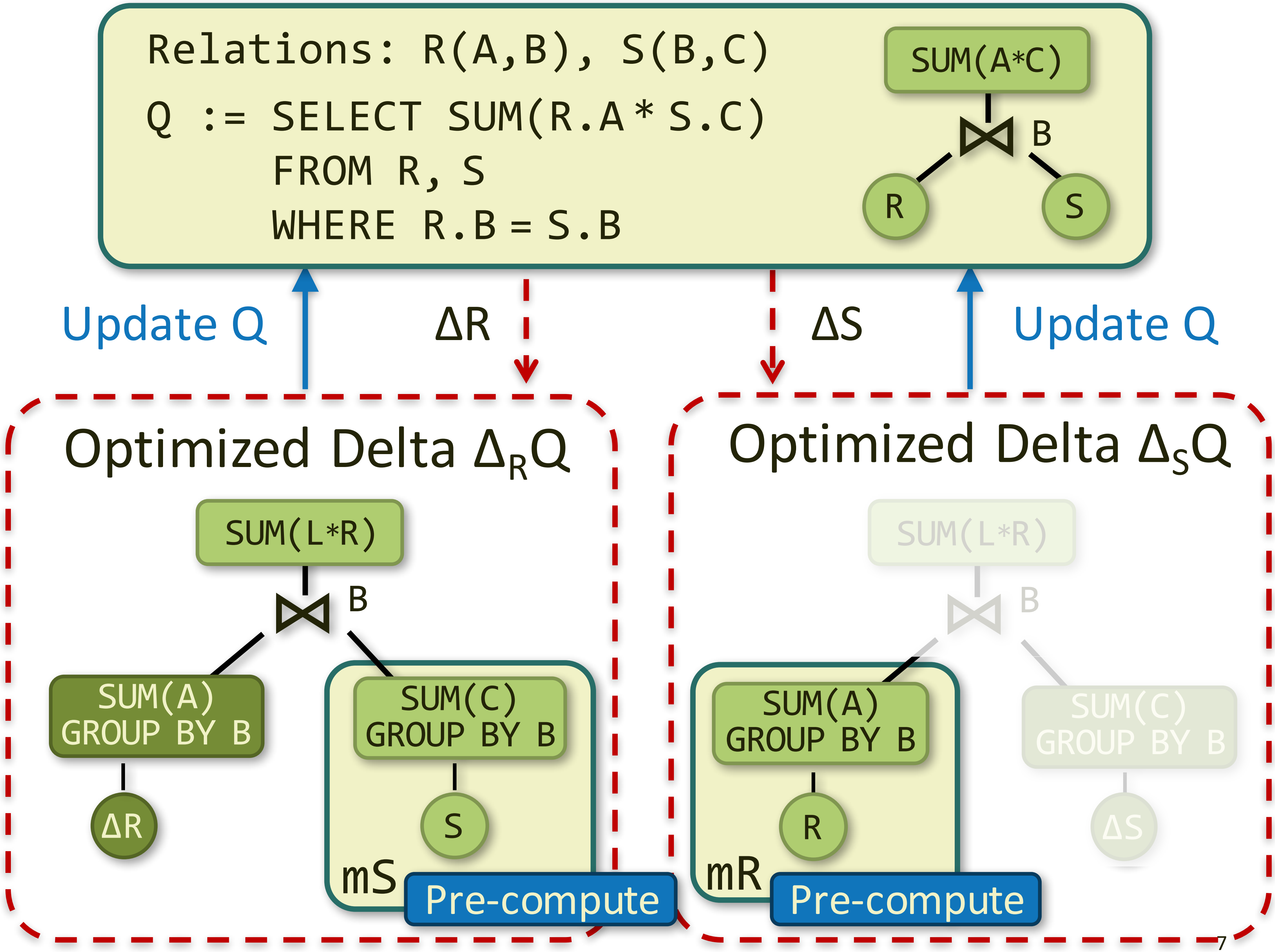
PROBLEM: DBMS & stream engines with classical IVM can have poor performance on fast, long-lived data

OUR APPROACH: Compilation of SQL queries into incremental engines

TOASTER = Recursive IVM + Code Generation (C++, Scala, Spark)

PERF: Million view refreshes/sec for single-tuple updates


Relations: R(A,B), S(B,C)
Q := SELECT SUM(R.A * S.C)
FROM R, S
WHERE R.B = S.B
SUM(A*C)
B
R
S
Delta for ΔR
Update Q
Optimized Delta $\Delta_R Q$
SUM(L*R)
B
SUM(A)
GROUP BY B
SUM(C)
GROUP BY B
ΔR
S
Optimize
Delta $\Delta_R Q$
SUM(A*C)
B
ΔR
S


Relations: R(A,B), S(B,C)
Q := SELECT SUM(R.A * S.C)
FROM R, S
WHERE R.B = S.B
SUM(A*C)
B
R
S
Update Q
ΔR
ΔS
Update Q
Optimized Delta Δ_R Q
SUM(L*R)
B
SUM(A)
GROUP BY B
ΔR
SUM(C)
GROUP BY B
S
mS
Pre-compute
Optimized Delta Δ_S Q
SUM(L*R)
B
SUM(A)
GROUP BY B
R
mR
Pre-compute
SUM(C)
GROUP BY B
ΔS

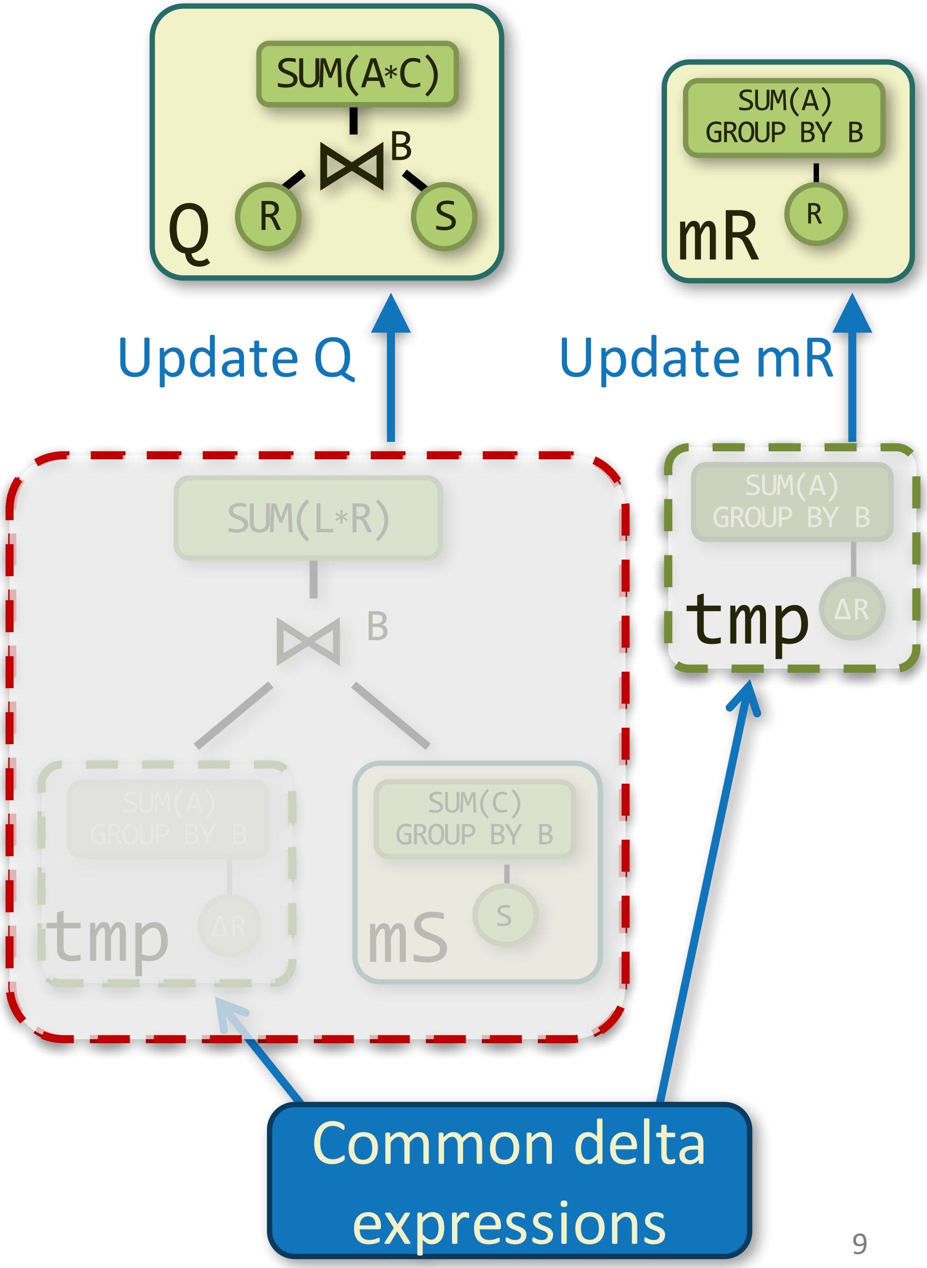
BATCH TRIGGER

ON UPDATE R BY ΔR:

```
// Pre-aggregate batch
tmp[B] := SELECT B, SUM(A)
             FROM ΔR
             GROUP BY B

// Update Q
Q  += SELECT SUM(tmp.V*mS.V)
         FROM tmp, mS
         WHERE tmp.B = mS.B

// Update mR
mR[B] += SELECT * FROM tmp
```



BATCH TRIGGER

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ON UPDATE R BY ΔR:

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  tmp[B] := SELECT B, SUM(A)
              FROM ΔR
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  // Update Q
  Q  += SELECT SUM(tmp.V*mS.V)
          FROM tmp, mS
          WHERE tmp.B = mS.B

  // Update mR
  mR[B] += SELECT * FROM tmp
```

BATCH C++

```
void onUpdateR(List<T> dR) {
  // Pre-aggregate batch
  HashMap<int,int> tmp;
  foreach (dA,dB) in dR
    tmp[dB] += dA;

  // Update Q (of type int)
  foreach (k,v) in tmp
    Q += v * mS[k];

  // Update mR
  foreach (k,v) in tmp
    mR[k] += v;
}
```

SINGLE-TUPLE C++

```
void onUpdateR(int dA, int dB) {
  Q += dA * mS[dB];
  mR[dB] += dA;
}
```

BASELINE

BATCH C++

```
void onUpdateR(List<T> dR) {
  // Pre-aggregate batch
  HashMap<int,int> tmp;
  foreach (dA,dB) in dR
    tmp[dB] += dA;

  // Update Q (of type int)
  foreach (k,v) in tmp
    Q += v * mS[k];

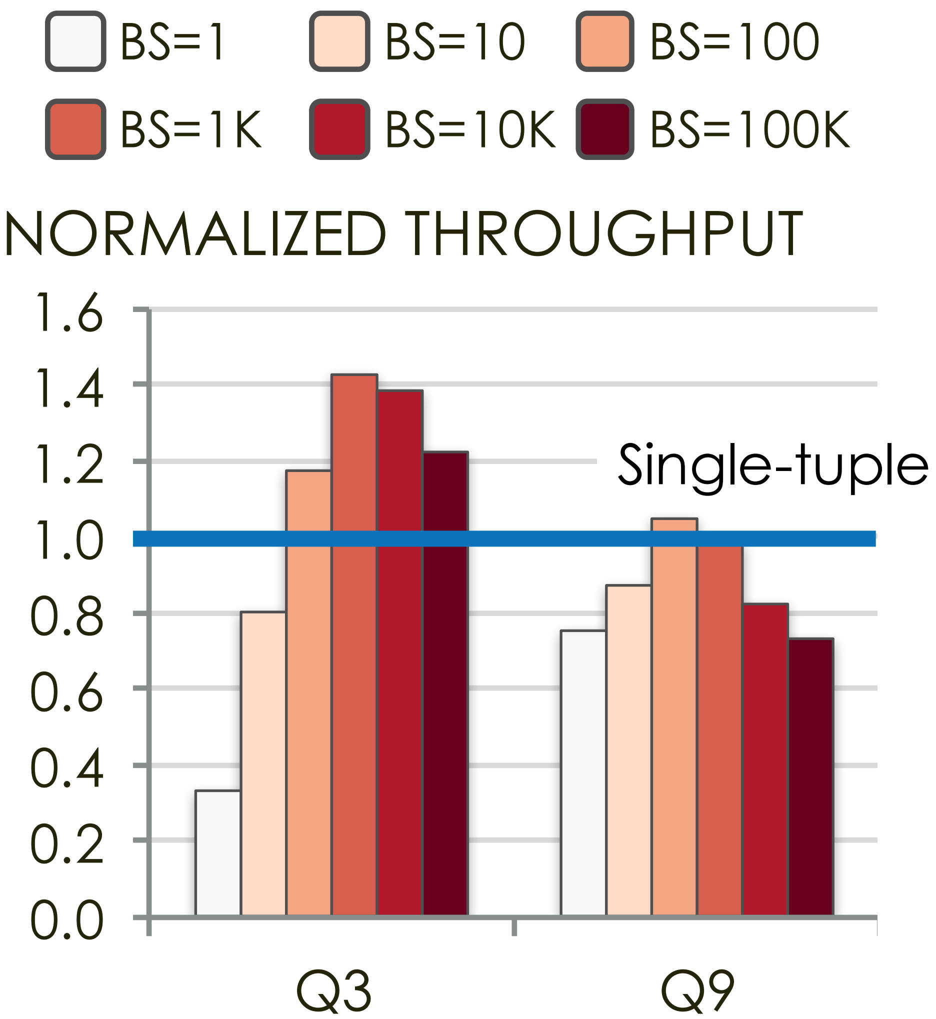
  // Update mR
  foreach (k,v) in tmp
    mR[k] += v;
}
```

CODE SPECIALIZATION

- Primitive-type parameters
- No intermediate maps
- Loop elimination
- Partial evaluation, inlining

SINGLE-TUPLE VS. BATCH IVM

TPC-H, 10GB stream, batch size = 1…100,000, C++



MAIN RESULTS

1) Best performance w/ medium batch sizes (= *bite sizes*)

2) Single-tuple processing faster for 5 queries; 7 queries within 20% of best-batch performance

3) Batch pre-aggregation can enable cheaper maintenance

4) OOM faster than DBMS

DISTRIBUTED IVM

DESIGN CHOICE 1:

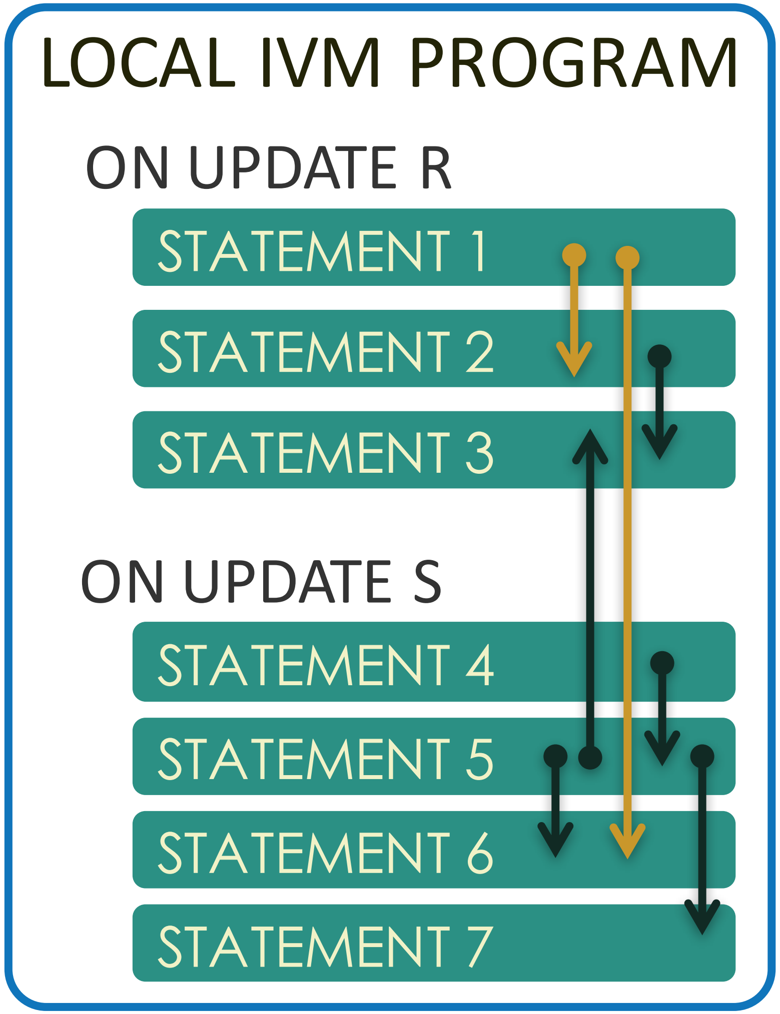
Local ➞ Distributed programs

CHALLENGE:

Dependencies among statements prevent arbitrary re-orderings

DESIGN CHOICE 2:

Synchronous execution model (on top of Spark)

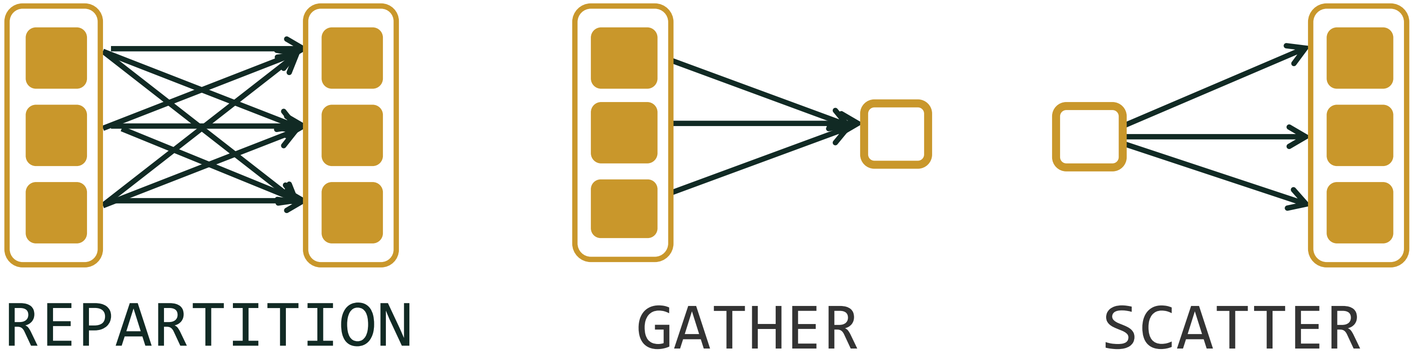


OUR APPROACH

LOCATION TAGS: LOCAL, PARTITIONED BY KEY, RANDOM

Annotate each node in query plan with location info

LOCATION TRANSFORMERS: Insert communication operations into query plan to preserve query semantics



HOLISTIC OPTIMIZATION: Minimize network cost

CONCLUSION

Much more in the paper:

- Single-tuple vs. batch incremental processing (single-tuple can be better!) + more experiments
- Distributed IVM (+ optimization framework)
- IVM of queries with nested aggregates
- Code and data-structure specialization

Download: http://www.dbtoaster.org