Column-Stores vs. Row-Stores: How Different Are They Really?

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Presented by Guozhang Wang
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Several slides are from Daniel Abadi and Michael Stonebraker

Column Stores for Read-Mostly Data Warehouses

- Storage-Level
  - Vertical Partitioning (VLDB 05)
  - Column-Specific Compression (SIGMOD 06)
- Executer-Level
  - Fast Join using Positions (VLDB 05)
  - Compressed Query Execution (SIGMOD 06)
  - Late Materialization (ICDE 07)

One Question:

- Do you really need to buy a Vertica or Sybase IQ?
  - Can we adapt our row-store to get column-store performance? Currently No
  - If not, what makes column-store not simulatable?

  Optimizations at query execution level

On the Other Hand…

- Directly comparing row-store with column-store is difficult
  - Some performance differences are fundamental differences between column stores and row stores
  - While some others are implementation artifacts.

Comparison Methodology

- Compare row-stores with row-stores and column-stores with column-stores.
  - Compare row-stores with "column like" row-stores.
  - Compare column-stores with "row like" column-stores

The Benchmark – SSBM

- Most (if not all) warehouses use star or snowflake schema
- Star Schema Benchmark (SSBM) is a simplified derivation from TPC-H
- One fact table (17 columns, 60,000,000 rows), and four dimension table (6 – 15 columns, at most 80,000 rows)
- Four types of queries, joining at most 3 dimensional tables

Row-Store Execution

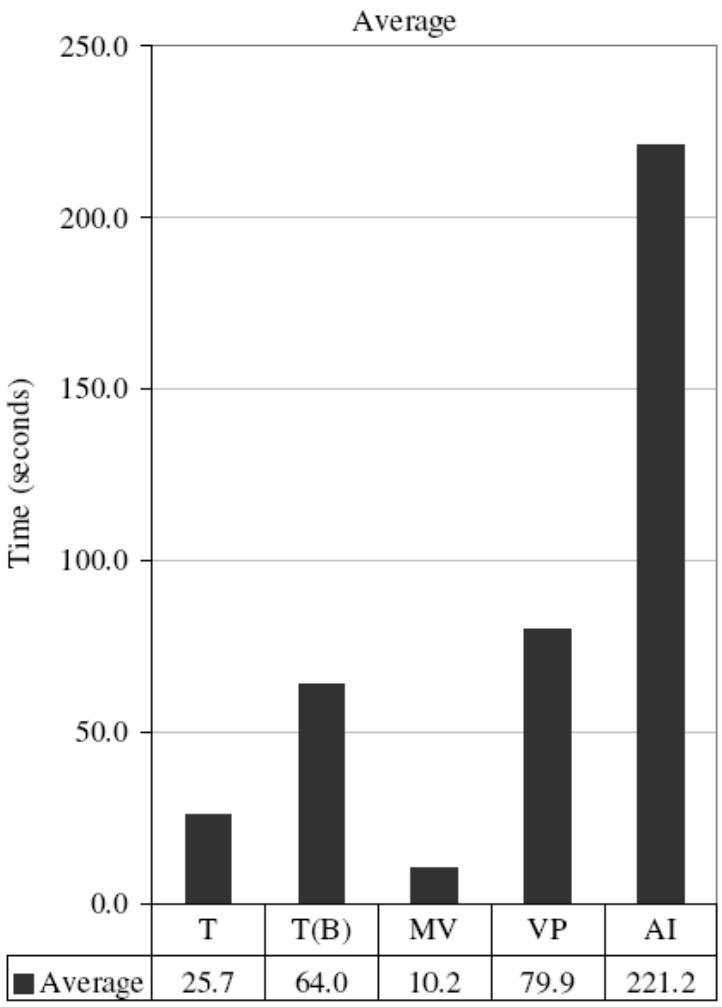
- Vertical Partitioning
  - each attribute is a two-column table: (values, position)
- Index-All
  - unclustered B+Tree index for every column of every table
- Materialized View
  - ***optimal*** set of materialized views for every query

Experiments: Row vs. Row

MV
Materialized View

VP
Vertcal Partitioning

AI
Index-All

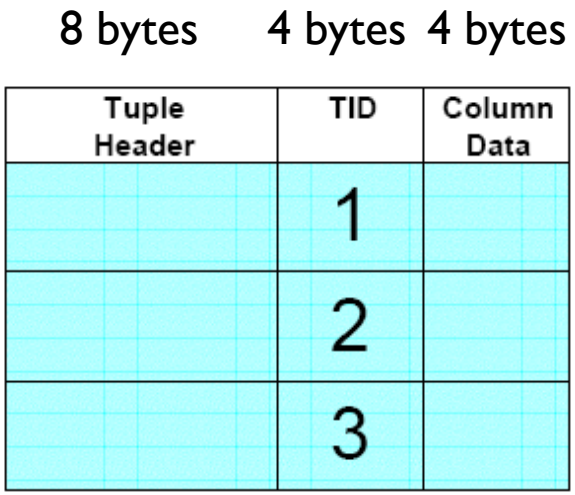


Reasons

- Tuple header overhead for VP
  - Complete f_table takes up

    ~4 GB (compressed)
  - VP tables take up

    0.7-1.1 GB each (compressed)



- Hash join is slow
  - But is probably the best option for Index-all

Part of this slide comes from Daniel Abadi

Conclusion 1

- Index-all approach is a poor way to simulate a column-store
  - it forces system to join columns at the beginning, but cannot defer them
- Problems with vertical partitioning are NOT fundamental
  - its disadvantages can be alleviated

Column-Store Execution

- Compression
- Late Materialization
- Block Iteration
- Invisible Join
  - move predicates on d_table to f_table to minimize out-of-order value extractions.

Removing these optimizations gives a "row-store like" column-store

Experiments: Col vs. Col

T vs. t

Tuple vs. Block

I vs. i

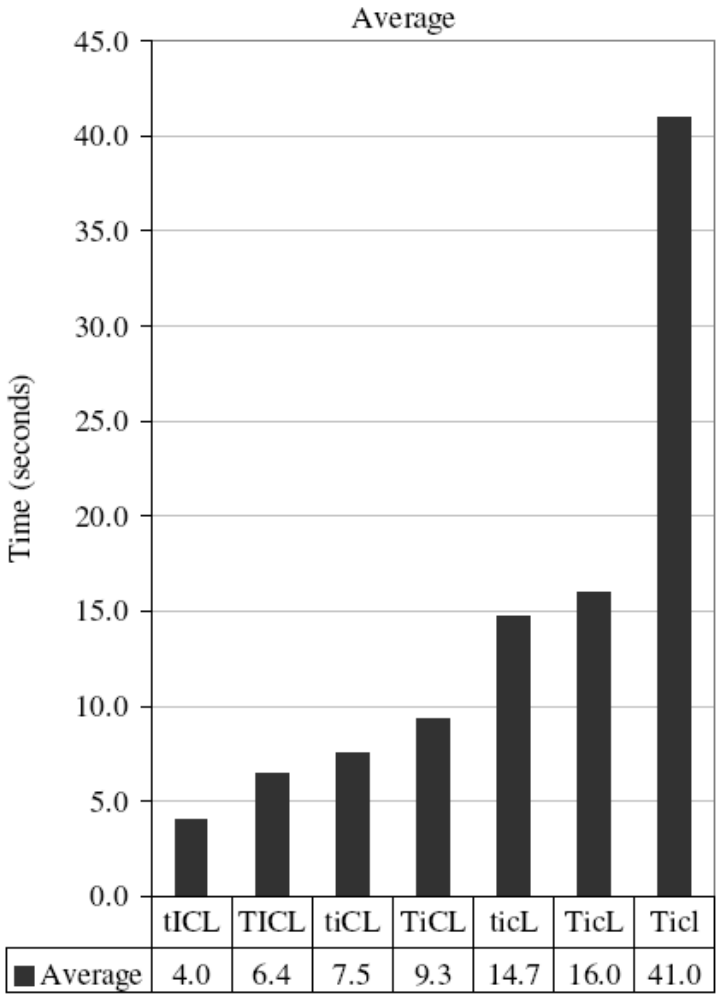
Invis. Join vs. Disabled

C vs. c

Comp. vs. Disabled

L vs. l

Late Mat. vs. Disabled



Performance Analysis

- Block: 5% - 50% depending on compression
- Invisible Join: 50% - 75%, but it is special optimization for star schemas
- Compression: almost x2 averagely, while x10 on sorted data
- Late materialization: x3 because of selective predicates

Conclusion II

- The most significant optimizations are compression and late materialization
- After all the optimizations are removed, the column store acts just like a row store
- Invisible join works so well that denormalization is not very useful for column store

Answer to the Question:

Can we adapt a row-store to get column-store performance?

- It might be possible, BUT:
  - need better support for vertical partitioning at the Storage Level
    - store tuple header separately
    - virtual record-id
  - need support for column specific optimizations at the Executer Level
    - late materialization
    - direct operator on compressed data

Questions?

One Size Fits All? – Part 2: Benchmarking Results

Michael Stonebraker, et al

One Size for All DBMS Needs?

- In the 1970s
  - Killer application: transaction processing
  - Relational gold standard
    - Record stored contiguously on disk
    - B-Tree indexing
    - Row-oriented query optimizer and executor
    - More...
- Over the years
  - New needs appear: XML, Data Warehouses…
  - New features are added in order to continue selling the original structure for these needs.

However…

- OSFA RDBMS is losing
  - To proprietary file systems in text search engines (GFS, Bigtable)
  - To column store systems in data warehouses (Vertica)
  - To specialized designed engine in stream processing (StreamBase)
  - To customized tools in scientific and intelligence data bases (Matlab)

Benchmark Results

- Telco Call Benchmark
  - Vertica 47X on 1/100 the hardware cost
- SSBM
  - Vertica 8X in ½ the space
- Split Adjusted Price & Forward First Arrival
  - StreamBase 25X if required state implemented as an RDBMS table
- Dot Product & Matrix Multiplication
  - ASAP 100X against RDBMS, and 10X against Matlab

ASAP Design

- ChunkyStore: like vertical partition, linear algorithm to read each chunk just once
- Compression: like column-specific compression, delta encode arrays
- Integration of "Cooking" and Storage: like WS and RS, same data model
- Data Uncertainty: convert between $R_{1,2,3}$
  - Value-probability pair: accurate
  - Expectation-variance pair: performance
  - Upper-lower bound pair

Reason?

- Different applications have different characteristics and requirements
  - Text search: semi/no structure, relaxed answers, no transaction…
  - Data warehouse: few uploads, ad hoc reads, star schema tables…
  - Stream processing: main memory storage, single tuple processing…
  - Scientific computation: Multi-D array storage, uncertainty management…

Conclusion

- Conflicting application requirements need custom architectures: OSFA is no longer true.
- What is next to OSFA DBMS?
  - No change: one RDBMS with high end specialization
  - K systems united by common parser
  - Data federations of incompatible systems
  - A scratch rewrite? (much more general engine which encompass all the requirements)

Obvious Research Agenda

- Find a market where OSFA doesn't work and customers are in pain
- Figure out what does

This slide comes from Michael Stonebraker

Thanks