Tackling The Challenges of Big Data

Big Data Storage

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Modern Databases

Introduction

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History Lesson

• 1970’s: relational model invented
• 1984: DB2 released, RDBMS declared mainstream
• Circa 1990: RDBMS takes over
  – “One-size fits all”
  – I’m the guy with the hammer; everything is a nail
• 2006: ICDE paper
  – “One-size does not fit all”
  – Co-existence of several solutions
• 2013: One size fits none
**Traditional RDBMS Wisdom**

- Dynamic row-level locking
- Aries-style write-ahead log
- Replication (asynchronous or synchronous)
  - Update the primary first
  - Then move the log to other sites
  - And roll forward at the secondary(s)

**Traditional RDBMS Wisdom**

- Data is in disk block formatting (heavily encoded)
- With a main memory buffer pool of blocks
- Query plans
  - Optimize CPU, I/O
  - Fundamental operation is read a row
- Indexing via B-trees
  - Clustered or unclustered

**My Thesis**

**Current RDBMSs (the elephants)**

- All date from the 1980’s
- Are legacy systems
- Are currently not good at anything
- Suffer from “The Innovators Dilemma”
- Deserve to be sent to the home for tired software
Rest of this Module

- I will explain why one size fits none
- Three main DBMS markets
  - One-third data warehouses
  - One-third OLTP
  - One-third everything-else
- Some conclusions at the end
Data Warehouse Marketplace

• Column stores are well along at replacing row stores
• Because they are a factor of 50 – 100 faster

Why???

• Most warehouses have a central fact table
  – Who bought what item in what store at what time.
• Surrounded by “dimension” tables
  – Store, time, product, customer, ...
• So-called “star/snowflake schema”
  – Check out anything written by Ralph Kimball for lots of detail

Why???

• Typical warehouse query reads 4-5 attributes from a 100 column fact table
  – Row store – reads all 100
  – Column store – reads just the ones you need
• Compression is way easier and more productive in a column store
  – Each block has only one kind of attribute
Why???

- No big record headers in a column store
  - They don't compress well
- A column executor is wildly faster than a row executor
  - Because of “vector processing”
  - See pioneering paper by Martin Kersten on this topic

The Participants

- Native column store vendors
  - HP/Vertica, SAP/Hana, Paracel (Amazon), SAP/Sybase/IQ
- Native row store vendors
  - Microsoft, Oracle, DB2, Netezza
- In transition
  - Teradata, Asterdata, Greenplum

Three Slides on Vertica

Table is decomposed into a collection of materialized views, stored by column and sorted on all attributes left-to-right
Three Slides on Vertica

• A column is stored in 64K "chunklets". 1st attribute is stored uncompressed, remainder are compressed (delta compression, lempel-zipf, repeated values, huffman, ...)

• Left-most column is usually delta encoded

• Chunklets are decompressed only when necessary

• Fundamental operation is “process a column”

Three Slides on Vertica

• To load fast, there is a main memory row-store in front of this column store.
  – Newly loaded tuples go there
  – In bulk, groups of rows are sorted, converted to column format and compressed
  – And written to new disk segments
  – Segment merge makes these segments bigger and bigger
  – Queries go to both places

Roughly Speaking

• This architecture also describes Paraccel and Hana

• It has nothing to do with the traditional RDBMS wisdom

• Over time the only successful warehouse products will be column stores

• The elephants have an “Innovator’s Dilemma” problem
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Data Warehouses

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OLTP Data Bases -- 3 Big Decisions

• Main memory vs disk orientation
• Replication strategy
• Concurrency control strategy
Reality Check on OLTP Data Bases

- TP database size grows at the rate transactions increase
- 1 Tbyte is a really big TP data base
- 1 Tbyte of main memory buyable for around $30K (or less)
  - (say) 64 Gbytes per server in 16 servers
- If your data doesn’t fit in main memory now, then wait a couple of years and it will....

Reality Check – Main Memory Performance

- TPC-C CPU cycles
- On the Shore DBMS prototype
- “Elephants” should be similar

To Go Fast

- Must focus on overhead
  - Better B-trees affects a small fraction of the path length
- Must get rid of all four pie slices
  - Anything less gives you a marginal win
  - Times10 as an example
Single Threading

- Toast unless you do this
  - Unless you get rid of queuing (somehow)
  - Or eliminate shared data structures (somehow)

- H-Store (and VoltDB) statically divide shared memory among the cores
  - Would be interesting to look at more flexible schemes

Main Memory

- Again, you’re toast unless you do this

- What happens if my data doesn’t fit?
  - See VLDB ’14 paper by Debrabant et. al.

Concurrency Control

- MVCC popular (NuoDB, Hekaton)

- Time stamp order popular (H-Store/VoltDB)

- Lightweight combinations of time stamp order and dynamic locking (Calvin, Dora)

- I don’t know anybody who is doing normal dynamic locking
  - It’s too slow!!!
What about Logging?

- Command logging much faster than data logging
  - See ICDE '14 paper by Malviya
- HA is now a requirement
  - Failover to a replica; rarely recover from a log

The Old Way vs The New Way

- Main memory not disk
- Anti-caching not caching
- Command logging not data logging
- Failover not recovery from a log
- MVCC or timestamp order not dynamic locking
- Single threaded not multi-threaded

New Way Systems

- Hekaton (Microsoft)
- Hana (SAP)
- VoltDB, MemSQL, SQLFire, ...
Summary

• New is a factor of 100 or so faster than old
• If you don’t care about performance, then stay with the elephants
• Otherwise, a changeover is in your future

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OLTP

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Everything Else

- NoSQL
- Array stores
- GraphDBMSs
- Hadoop

NoSQL – 75 or so Vendors

- Give up SQL
  - Completely misguided
  - SQL is compiled (at compile time) into the low level utterances of the NoSQL folks
  - Nobody codes in assembler any more!!!
  - Never bet against the compiler!!

NoSQL – 75 or so Vendors

- Give up ACID
  - If you are guaranteed that you won’t need it (now or in the future) then you are ok
  - Otherwise, your hair will be on fire
NoSQL – 75 or so Vendors

- Schema later
  - Most support semi-structured data – adding a new “column” is trivial
  - Don’t have to think about your data upfront
  "Good or bad depending on your point of view"

NoSQL – Summary

- Moving quickly toward SQL
  - Cassandra and MongoDB are moving to (yup) SQL

- Moving toward ACID
  - Even Jeff Dean (Google) now admits ACID is a good idea

- NoSQL
  - Used to mean “No SQL”
  - Then meant “Not only SQL”
  - Moving toward “Not yet SQL” (i.e. convergence)

NoSQL – Summary

- Systems are fine for “low end” applications
  - E.g. webby things
  - E.g. protection/ authentication data bases
  - Etc.
Array DBMSs and Complex Analytics

- Machine learning
- Data clustering
- Predictive models
- Recommendation engines
- Regressions
- Estimators

i.e. "Data Mining"

Complex Analytics

- By and large, they are defined on arrays
- As collections of linear algebra operations
- They are not in SQL!
- And often
  - Are defined on large amounts of data
  - And/or in high dimensions

Complex Analytics on Array Data – An Accessible Example

- Consider the closing price on all trading days for the last 20 years for two stocks A and B
- What is the covariance between the two time-series?
  \[(1/N) \times \text{sum}((A - \text{mean}(A)) \times (B - \text{mean}(B)))\]
Now Make It Interesting ...

- Do this for all pairs of 15000 stocks
  - The data is the following 15000 x 4000 matrix

<table>
<thead>
<tr>
<th>Stock</th>
<th>t1</th>
<th>t2</th>
<th>t3</th>
<th>t4</th>
<th>t5</th>
<th>t6</th>
<th>t7</th>
<th>...</th>
<th>t4000</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>S2</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Array Answer

- Ignoring the (1/N) and subtracting off the means ....
  
  \[ \text{Stock} \times \text{StockT} \]

System Requirements

- Complex analytics
  - Covariance is just the start
  - Defined on arrays!!

- Data management
  - Leave out outliers
  - Just on securities with a market cap over $10B

- Scalability to many cores, many nodes and out-of-memory data
**Array DBMSs -- e.g. SciDB**

- **Array SQL**
  - For joins filters, ...

- **Built in functions**
  - For SVD, Co-variance, eigenvalues, ...

- **User-defined extensions**
  - If you don’t see what you need

**Array DBMSs -- Summary**

- **Will get tractions**
  - When the world moves to complex analytics

- **Don’t look at all like the traditional wisdom**

**Graph DBMSs**

- **Focus on things like Facebook/twitter graphs**

- **OLTP focus** (Neo4J)

- **Analytics focus** (shortest path, minimum cut set, ...)  

- **Can you beat**
  - RDBMS simulations
  - Array simulations

- **Jury is still out**
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Everything Else

THANK YOU

What is Hadoop?

• Open source version of Google's Map-Reduce

• Two operations
  - Map (basically filter, transform)
  - Reduce (basically rollup)

• Very good for "embarrassingly parallel" operations
  - E.g. document search

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The Hadoop Stack

- Hive (or Pig) at the top
  - Think SQL
- Hadoop (Map-Reduce) in the middle
- HDFS (a file system) at the bottom
- Runs across any number of nodes
  - Scalable!

Possible Uses for Hadoop Stack

- Embarrassingly parallel computations
- SQL aggregates (e.g. warehouse-style queries)
  - Factor of 100 worse than a warehouse DBMS
- Complex analytics
  - Factor of 100 worse than an array DBMS
- Scientific codes (e.g. computational fluid dynamics)
  - Factor of 100 worse than MPI-based systems

Hadoop Usage at Facebook

- 95+% Hive
  - For which Hadoop layer is a disaster
**What is Happening Now?**

- Cloudera, Hortonworks and Facebook are ALL doing the same thing
  - Defining and building an execution engine that processes Hive without using Hadoop layer

- Effectively moving to compete in the warehouse market
  - All warehouse vendors have Hive interfaces

**Most Likely Future**

- There is a small market for embarrassingly parallel Hadoop framework

- There is a much bigger market for a Hive-SQL framework
  - Execution engines will look like data warehouse products

- HDFS may or may not survive
  - It is also horribly inefficient

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**Modern Databases**

**Hadoop**

THANK YOU
Thoughts While Shaving

- Warehouses will be a column store market
  - If you are not running one now, you will have to switch
  - Ask your vendor what his column store plans are

- OLTP will be a main memory market
  - If you are not running one now, you will have to switch
  - Ask your vendor what his main memory plans are

- Array DBMSs and Graph DBMS may get traction
  - You should (at the very least) understand what they are good for

- NoSQL
  - Is popular for low-end applications
  - Especially document management, web stuff and places where you want schema-later
  - ACID-less
Thoughts While Shaving

- The Hadoop stack will morph into something completely different
  - Hold onto your seat belt!!
  - At the very least -- see if you are contemplating embarrassingly parallel applications -- if not, you are in deep doo-doo

- Current elephant products will only survive long-term in low performance applications

The Curse -- May You Live in Interesting Times

- Lots of new DBMS ideas and products!!!

- BI folks will keep more and more stuff
  - Warehouses will get bigger and bigger

- Sea change from simple analytics to complex analytics expected

- The “internet of things” is a force to be dealt with
  - i.e. everything on the planet of material significance will be sensor-tagged -- generating yet more data deluge

The Curse -- May You Live in Interesting Times

Hire a really really good chief data officer to help you sort out the future
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