Tackling The Challenges of Big Data

Big Data Storage

Michael Stonebraker

Professor

Massachusetts Institute of Technology

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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**

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Data Warehouses

Michael Stonebraker

Professor

Massachusetts Institute of Technology

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???

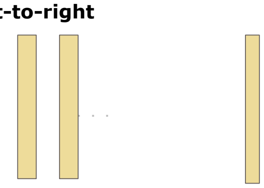
- **No big record headers in a column store**
  - They don't compress well
- **A column executor is wildly faster than a row executor**
  - Because of "vector processing"
  - See pioneering paper by Martin Kersten on this topic

The Participants

- **Native column store vendors**
  - HP/Vertica, SAP/Hana, Paraccel (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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OLTP

Michael Stonebraker

Professor

Massachusetts Institute of Technology

OLTP Data Bases -- 3 Big Decisions

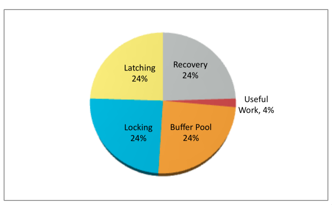
- **Main memory vs disk orientation**
- **Replication strategy**
- **Concurrency control strategy**

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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Everything Else

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Massachusetts Institute of Technology

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) * sum (Ai - mean(A)) * (Bi - mean (B))

Now Make It Interesting …

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

Stock	t_1	t_2	t_3	t_4	t_5	t_6	t_7	….	t_{4000}
S_1									
S_2									
…									
S_{15000}									

Array Answer

- **Ignoring the (1/N) and subtracting off the means ….**

Stock * StockT

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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**

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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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Hadoop

Michael Stonebraker
Professor
Massachusetts Institute of Technology

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

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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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

Thoughts While Shaving

- **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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