Blink: Not Your Father’s Database!

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Blink – Agenda

- Why and What is Blink
- Blink Market – Business Intelligence
  - Blink Architecture
  - It’s All About Performance!
  - What’s the Big Deal?
  - Behind the Curtain – The Query Engine Technology
- References and Related Work
- Next Steps
- Conclusions
Motivation

• Today, performance of Business Intelligence (BI) queries is too unpredictable
  – When an analyst submits a query, s/he doesn’t know whether to:
    • Wait for the response
    • Go out for coffee
    • Go out for dinner
    • Go home for the night!
  – Response time depends upon “performance layer” of indexes & materializations
  – Depends critically on predicting the workload
  – But BI is inherently ad hoc!

• Goal of Blink:
  Predictably Fast (i.e., Interactive) Ad Hoc Querying
  – Any query should run in about the same time
  – Permit an Analyst to interact with the data
What Is Blink?

• **Accelerator technology** developed by IBM Almaden Research since 2007
• Contains a compressed **copy** of a (portion of a) data warehouse
• Exploits:
  – Large main memories
  – Commodity multi-core processors
  – Proprietary compression
• Speeds up typical **Business Intelligence** SQL queries by **10x to 100x**
• Without requiring tuning of indexes, materialized views, etc.

• **Products offered by IBM based upon Blink:**
  – **IBM Smart Analytics Optimizer for DB2 for z/OS V1.1** – GA’d Nov. 2010
    • Appliance: Runs on zEnterprise Blade eXtension (zBX), network-attached to zEnterprise
  – **Informix Warehouse Accelerator** – GA’d March 2011
    • Virtual Appliance: Runs in same machine as Informix IDS
Target Market: Business Intelligence (BI)

- Characterized by:
  - "Star" or "snowflake" schema:
    - "Star" or "snowflake" schema:

- Complex, ad hoc queries that typically
  - Look for trends, exceptions to make actionable business decisions
  - Touch large subset of the database (unlike OLTP)
  - Involve aggregation functions (e.g., COUNT, SUM, AVG,...)
  - The "Sweet Spot" for Blink!
What Blink is Designed For

- **OLAP-style SQL queries:**
  - Relational star schema (large fact table joined to multiple dimensions)
  - Large subset of data warehouse accessed, reduced significantly by...
  - Aggregations (SUM, AVG, COUNT) and optional grouping (GROUP BY)
  - Looking for trends or exceptions

- **EXAMPLE SQL:**

```sql
SELECT P.Manufacturer, S.Type, SUM(Revenue)
FROM Fact_Sales F
  INNER JOIN Dim_Product P ON F.FKP = P.PK
  INNER JOIN Dim_Store S ON F.FKS = S.PK
  LEFT OUTER JOIN Dim_Time T ON F.FKT = T.PK
WHERE P.Type = 'JEANS` AND S.Size > 50000 AND T.Year = 2007
GROUP BY P.Manufacturer, S.Type
```
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**Host DBMS (DB2 or IDS):**
- Routes SQL queries to accelerator
- User need not change SQL or apps.
- No externalized interfaces!
- Can always run query in Host DBMS, e.g., if
  - too complex SQL, or
  - too short an est. execution time

**Blink:**
- Commodity blades
- Connects to Host DBMS via TCP/IP & DRDA
- Analyzes, compresses, and loads
  - Copy of (portion of) warehouse
  - Partitioned among nodes
- Processes routed SQL query and returns answer to Host DBMS
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Blink Accelerates Most the Longest-Running Queries

Average Speed-up = 85x
Blink Query Execution times (magnified)

All Queries: 11-26 Secs.
Blink Query Execution times (magnified)

Execution Time (in Seconds)

- ISAO Dec. 2008
- ISAO Oct. 2009

Customer Query Number

Q1200 Q2100 Q2300 Q3211 Q3224 Q4400 Q5200

- 11-26 Secs.
- 3-8 Secs.

All Queries: 11-26 Secs.
All Queries: 3-8 Secs.!!!
Beta Test – Blink Elapsed Time & Speedup

- Q122: 1.2x
- Q185: 2.5x
- Q90: 3.6x
- Q115: 11.3x
- Q98: 16.4x
- Q145: 17.4x
- Q263: 129x!!!
- Q184: 378x!!!
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- Blink Architecture
- It’s All About Performance!

**What’s the Big Deal?**
- The Query Engine Technology
- Behind the Curtain – The Query Engine Technology
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What’s the Big Deal? What’s so Disruptive?

• **Blink rides the wave of hardware technology trends:**
  – Multi-core processors
  – Large main memories
  – Fast interconnects
  – Increasing latency gap between DRAM and disk

• **Blink disrupts at least 4 major tenets that have been held sacrosanct for over 4 decades!**
Disruption 1 of 4

• **Tenet #1**: General-purpose DBMSs are most cost-effective

• **Consequence of Tenet #1**: BI pays for OLTP overheads
  – Locking
  – Logging

• **Disruption #1**: Specialized DBMSs for BI now commonplace in market!

• **Consequences of Disruption #2**:
  – BI uses snapshot semantics (typically roll-in or roll-out in batches of rows)
  – Can simplify and eliminate OLTP overheads
  – Can still embed specialty engines in general-purpose DBMS!
    • “Workload-optimized systems”
- **Tenet #2:** Data warehouses are too big for memory
- **Consequence of Tenet #2:** Disk I/O concerns dominate DBMS...
  - Costs
  - Performance
  - Administration efforts
- **Disruption #2:** Huge, cheap main memories (RAM) and flash memories
- **Consequences of Disruption #2:**
  - Portions of warehouse can fit, if partitioned among multiple machines
  - Compression helps!
  - New bottleneck is memory bandwidth (RAM ↔ L2 cache) and CPU
  - No preferred access path

\[ \text{Data warehouse} = 800 \text{ lbs.} \]
Disruption 3 of 4

- **Tenet #3:** Need many Indexes & MQTs for scalable OLAP performance
  - **Consequences of Tenet #3:**
    - Need an optimizer to choose among access paths
    - Need a ★★★★★ wizard to design “performance layer” (expensive!)
    - Must anticipate queries
    - Large time to update performance layer when new data added

- **Disruption #3:** Massive parallelism achieves DB scan in seconds!
  - Arbitrarily partition database among nodes (32–64 GB RAM / node)
  - Exploit multi-core architectures within nodes (1 user or DB cell / core)

- **Consequences of Disruption #3:**
  - Only need to define 1 view in DB2 to satisfy many queries on the accelerator
  - Always scan tables!!
  - Accelerator automatically does equivalent of partition elimination
    - If literal is not in dictionary of that partition
    - Accelerator itself doesn’t need
      - Performance layer (indexes or materialized views)!
      - Optimizer!
  - **Simpler! (no need for 4-star wizard)**
  - Lower TCO!
  - Consistent response times
Disruption 4 of 4

- **Tenet #4**: Main-memory DBMSs are the same as a big buffer pool
- **Consequence of Tenet #4**: Don’t need a special main-memory DBMS
- **Disruption #4**: Clever engineering can save lots more!
- **Examples of Disruption #4**:  
  - Specialized order-preserving & fixed-length compression within partitions permits:  
    - Faster access  
    - Performing most operations on encoded values  
      - Saves CPU for most processing and decoding  
      - More efficient use of cache and memory bandwidth  
    - **Simultaneous application of predicate conjuncts (1 compare!)**  
      - Cache-conscious algorithms make max. use of L2 cache and large registers  
      - Exploit multi-core processors  
      - Hash-based grouping avoids sorting
Blink’s “Secret Sauce”

1. **Operate on encoded data**
   - Dictionary compression with approximate Huffman encoding (fixed length within each part.)
   - **Most SQL operations on compressed data!**
   - Enables SIMD operations on multiple values in a register
   - Dramatically improves efficiency in utilization of RAM, cache, and memory bandwidth

2. **Register Store**
   - Pack several column values into a register
   - Access only columns referenced in query
   - Favors scan-based processing
   - L2 / L3 efficiency

3. **Parallelism**
   - KIWI: Kill It With Iron!
   - Multiple nodes (blades)
   - Designed and built for multi-core, from the ground up

<table>
<thead>
<tr>
<th>A, D, G</th>
<th>A, D, G</th>
<th>A, D, G</th>
<th>A, D, G</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 bits</td>
<td>4 bits</td>
<td>4 bits</td>
<td>4 bits</td>
</tr>
<tr>
<td>128 bits</td>
<td>128 bits</td>
<td>128 bits</td>
<td>128 bits</td>
</tr>
</tbody>
</table>
Blink’s “Secret Sauce”

**Single Instruction, Multiple Data (SIMD)**
- Enabled by encoded data and register store
- CPU vector processing
- Large gains in CPU efficiency
- 3rd level of parallelism!

**Architecture-conscious**
- Cache-conscious query evaluation
- Operate on groups of rows
- Scan-friendly

**Selection via Synopses**
- Skip entire blocks based upon meta-data
- No DBA action to define or use – truly invisible.
- Similar to Netezza’s “zonal maps”
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### Top 64 traded goods – 6 bit code

<table>
<thead>
<tr>
<th>Origin</th>
<th>USA</th>
<th>GER, FRA, …</th>
<th>Rest</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Histogram on Origin

- **Common Values**
- **Rare values**

### Table partitioned into Cells

- **Column Partitions**
  - **Origin**: USA, GER, FRA, …, Rest
  - **Product**: Cell 1, Cell 2, Cell 3, Cell 4, Cell 5, Cell 6

### Field lengths

- **Field lengths vary between cells**
  - Higher Frequencies → Shorter Codes (Approximate Huffman)
- **Field lengths fixed within cells**

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Query Processing

- Cell is also the unit of processing, each cell...
  - Assigned to one core
  - Has its own hash table in cache (so no shared object that needs latching!)
- **Main operator: SCAN over compressed, main-memory table**
  - Do selections, GROUP BY, and aggregation as part of this SCAN
  - Only need de-compress for arithmetic operations
- **Response time $\propto \frac{\text{database size}}{\text{(# cores x # nodes)}}$**
  - Embarrassing Parallelism – little data exchange across nodes
Fine-Grained Data Parallelism

Work Unit = Block of Frequency-Partitioned Cell

Thread 1

- simultaneous = range, short IN-list preds
- Residual preds, joins
- Hash GROUP BY
- Aggregations

Work Queue

Other Threads

Merge Results

- "fast path"
- operate on encoded values
- must decode values (math exprs.)
Blink PAX Data Storage Format – Overview

- **Frequency Partitioning into Cells**
  - Column-wise compression
  - Each col. dictionary partitioned by value frequency
  - Cross-product of col. partitions → Cells
  - Encoded columns are fixed-length (bits) in a cell

- **Cell data are stored in fixed-sized (1MB) Blocks**

- **Rows are partitioned vertically within blocks, into Banks**
  - Encoded columns are bin-packed into word-sized (8,16,32,64 bit) banks
  - **Vertical Banks**: contain columns typically used in predicates and grouping
  - **Horizontal Bank**: contains measure columns

- **Access Pattern**:
  - Scan V-banks to apply predicates.
  - RID access to V-banks for residual predicates, grouping columns.
  - RID access to H-bank for aggregation.
Banks and Tuplets in Blink

- A **bank** is a vertical partition of a table, containing a subset of its columns
  - Assignment of columns to banks is cell-specific, since column’s length
    - Varies from cell to cell, but
    - Is fixed within a cell
  - Banks contain
    - Concatenations of the fixed-length column codes
    - Padded to the nearest fraction of a word length (8 / 16 / 32 / 64 bits).
    - We call these word-sized units **tuplets**.

- Blink’s bank-major layouts are a **hybrid** of row-major and column-major

![Diagram of banks and tuplets](image)

- Bank β1 (32 bits)
- Bank β2 (32 bits)
- Bank β3 (16 bits)
Register Stores Facilitate SIMD Parallelism

- Access only the banks referenced in the query (like a column store):
  - SELECT SUM (T.G)
  - FROM T
  - WHERE T.A > 5
  - GROUP BY T.D

![Diagram showing bank access and data organization]
Register Stores Facilitate SIMD Parallelism

- Access only the banks referenced in the query (like a column store):
  - `SELECT SUM (T.G)`
  - `FROM T`
  - `WHERE T.A > 5`
  - `GROUP BY T.D`

- Pack multiple rows from the same bank into the 128-bit register

- **Enables yet another layer of parallelism: SIMD (Single-Instruction, Multiple-Data)!**
Simultaneous Evaluation of Equality Predicates

- CPU operates on 128-bit units
  - Lots of fields fit in 128 bits
  - These fields are at fixed offsets
  - Apply predicates to all columns simultaneously!
- Also works for range queries!

State == ‘CA’ && Quarter == ‘2011Q4’

State == 01001 && Quarter == 1110

Translation Value Query to Coded Query

State == 01001 && Quarter == 1110

<table>
<thead>
<tr>
<th>State</th>
<th>Quarter</th>
</tr>
</thead>
<tbody>
<tr>
<td>…</td>
<td>…</td>
</tr>
<tr>
<td>11111</td>
<td>0</td>
</tr>
<tr>
<td>01001</td>
<td>0</td>
</tr>
</tbody>
</table>

&

? ==

Row

<table>
<thead>
<tr>
<th>State</th>
<th>Quarter</th>
</tr>
</thead>
<tbody>
<tr>
<td>11111</td>
<td>0</td>
</tr>
<tr>
<td>11110</td>
<td>0</td>
</tr>
</tbody>
</table>

Selection result
No shuffle needed:
- Fact table partitioned among nodes and cores
- Dimension tables replicated

Basic idea: Re-write Join as multiple scans:
1. Over each dimension, to form:
   - A list of qualifying primary keys (PKs), decoded
   - A hash-map of primary key → auxiliary columns (those used later in query for GROUP BY, etc.)
2. Over fact table:
   - First convert PKs to foreign keys (FKs) in fact table column
   - Apply as (very big) IN-list predicates (a semi-join), one per dimension
   - Look up into hash-maps to pick up other columns
   - Complete Grouping and Aggregation

Snowflakes: apply repeatedly, outside in
What About Updates?

- Blink uses **snapshot semantics** (batch updates), common in BI
- System maintains a **currentEpoch** number (monotone increasing)
  - Think of it as a batch or version number
  - Prevents seeing incomplete updates, without needing locking
  - Bumped (N++) atomically after each batch of inserts & deletes completes
- Tables have two new columns
  - **startEpoch** – epoch in which that row inserted
  - **endEpoch** – epoch in which that row deleted (initially Infinity)
- Queries are automatically appended with two predicates:
  - startEpoch < currentEpoch AND
  - endEpoch > currentEpoch
- Encoding of updated values
  - If value is in dictionary, use that encoding
  - Otherwise, store unencoded in a special cell, called the “catch-all” cell
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Blink Refereed Publications

- **VLDB 2008**: “Main-Memory Scan Sharing for Multi-core CPUs”, Lin Qiao, Vijayshankar Raman, Frederick Reiss, Peter Haas, Guy Lohman

- **VLDB 2008**: “Row-Wise Parallel Predicate Evaluation”, Ryan Johnson, Vijayshankar Raman, Richard Sidle, Garret Swart

- **ICDE 2008**: “Constant-time Query Processing”, Vijayshankar Raman, Garret Swart, Lin Qiao, Frederick Reiss, Vijay Dialani, Donald Kossmann, Inderpal Narang, Richard Sidle

- **SIGMOD 2007**: “How to barter bits for chronons: compression and bandwidth trade offs for database scans”, Allison L. Holloway, Vijayshankar Raman, Garret Swart, David J. DeWitt

- **VLDB 2006**: “How to wring a table Dry: Entropy Compression of Relations and Querying Compressed Relations”, Vijayshankar Raman, Garret Swart
Related Work

• **SAP HANA / HYRISE**
  – claim OLTP and BI workloads
  – single copy
  – single node (HYRISE)

• **VectorWise**
  – pure column store, disk-based
  – single copy
  – single node

• **Vertica**
  – pure column store, disk-based
  – projections
  – many (specialized) kinds of compression

• **ParAccel, Exasol** – ??
Next Steps: BLink Ultra (BLU)

- What, you can’t afford to put 100 TB in RAM?
  - Relax main-memory-only to disk-based

- You say your dimension table has 2000 columns?
  - Allow and exploit pure column store

- You’ve got HOW MANY fact tables?

- Yikes, your dimension table is HOW BIG?
  - Allow multiple partitioned tables
  - Need traditional MPP optimization for join ordering

- Yeah, synchronizing multiple copies is a pain.
  - Have Blink store the only copy

- What, you have point queries, too?
  - May need some indexes

- Um, we haven’t implemented that yet...
  - Tighter coupling with traditional DBMS
Summary – Not Your Father’s Database!

• Radical changes are happening in hardware
  – Large, cheap memories
  – Multi-core processors promise cheap, massive CPU parallelism

• Blink exploits these trends:
  – Special-purpose accelerator (BI only, snapshot semantics, no transactions)
  – Main-memory DBMS
  – Massive parallelism of commodity multi-core hardware (blade center format)
  – Query processing on compressed values!
  – Cache-conscious algorithms

• Blink speeds up your problem queries the most!

• Blink is an appliance product that is transparent to the user
  – Minimal set-up
  – Applications need not change
  – Tuning not needed!
  – Lower TCO

Questions?
Evaluation of Range Predicates on Encoded Values

B <= ‘CA’ and C < 17 and D <= ‘Q4’

Translate value query to encoded query (exploits order-preserving code)

A <= 11111 and B <= 01000 and C <= 0011 and D <= 1110

General result: (UB – Tuple) xor (Tuple – LB) == UB xor LB
# Blink vs. a Column Store

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Column Store</th>
<th>Blink</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression</td>
<td>Every column padded to word boundary ➔ more padding/column ➔ worse compression</td>
<td>Multiple columns / word ➔ less padding overhead</td>
</tr>
<tr>
<td>Query Processing</td>
<td>- Like having an index on every column&lt;br&gt;- To answer query:&lt;br&gt;  - Determine list(s) of matching records&lt;br&gt;  - Intersect these lists on RID</td>
<td>- Can skip blocks based upon predicates&lt;br&gt;- To answer query:&lt;br&gt;  - Do table scan</td>
</tr>
<tr>
<td>Updating</td>
<td>- Insert requires:&lt;br&gt;  - Separate updates to every column ➔ Multiple random I/Os, 1/column</td>
<td>- Insert requires:&lt;br&gt;  - Single update to each bank, 1 / bank ➔ One I/O to one cell block</td>
</tr>
<tr>
<td>Evaluation Matches Hardware?</td>
<td>Evaluation doesn’t match w/ Hardware:&lt;br&gt;  - Index navigation involves random accesses&lt;br&gt;  - Index navigation involves branches&lt;br&gt;  - Predicate evaluation has to be done serially</td>
<td>Evaluation matches with Hardware:&lt;br&gt;  - Scan does sequential memory access&lt;br&gt;  - Almost no branches&lt;br&gt;  - Simultaneous predicate evaluation&lt;br&gt;  - SIMD predicate evaluation</td>
</tr>
</tbody>
</table>

**Query Processing**
- Like having an index on every column
- To answer query:
  - Determine list(s) of matching records
  - Intersect these lists on RID

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