Maximum Velocity MySQL

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MySQL

A Quick Survey

- So, how many are using...
  - 3.23? 4.0? 4.1? 5.0? 5.1?
  - MyISAM? InnoDB? Other?
  - Replication? Cluster? Partitioning?
  - Enterprise? Community?
  - PostgreSQL? Oracle? SQL Server? Other?
  - PHP? Java? C#/.NET? Perl? Python? Ruby? C/C++?

Get Your Learn On

- Profiling, benchmarking, EXPLAIN command
- Schema and indexing guidelines
- Black-belt SQL coding
- Tuning server settings

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Benchmarking, Profiling, and EXPLAIN Command

Benchmarking Concepts

- Allows you to track changes in your application and server environment over time
- Isolate to a single variable
- Record everything
  - Configuration files, OS/Hardware changes, SQL changes
- Shut off unecessary programs and network
- Disable query cache in MySQL

Your Benchmarking Toolbox

- ApacheBench (ab)
  - Excellent for simple web application benchmarks
- Sysbench, mysqlslap (5.1+), supersmack
  - MySQL-specific benchmarking tools
- Frameworks/harnesses reduce repetitive work
  - MyBench
  - JMeter/Ant
  - Custom scripting (most common)

Example simple benchmark script
benchmark-no-cache.sh

```
#!/bin/sh
# Restart Apache to ensure cleared buffers
sudo apache2ctl restart

# Restart MySQL
sudo /etc/init.d/mysql restart

# Kill any cached files
sudo rm -rf /var/www/apache2-default/benchmark/cache/*

# Warm up Apache with a simple page
ab -c 300 -n 2000 http://localhost/apache2-default/php-info.php >& /dev/null

echo "NO CACHE BENCHMARK RUN:" > no-cache-benchmark.results

# Reset the query cache and
# flush tables and status counters
mysql --skip-column-names --user=root < setup-benchmark.sql >> no-cache-benchmark.results

# Run the benchmark on the warmed-up server
ab -n 2000 -c 300 \
http://localhost/apache2-default/benchmark/test-no-cache.php >> no-cache-benchmark.results

#  Run the post-benchmark status script
mysql --skip-column-names --user=root < post-benchmark.sql >> no-cache-benchmark.results
```

Example simple benchmark result

benchmark-no-cache.result

```
NO CACHE BENCHMARK RUN:
<snip>
Concurrency Level:      300
Time taken for tests:   7.945251 seconds
Complete requests:      2000
<snip>
Requests per second:    251.72 [#/sec] (mean)
Time per request:       1191.788 [ms] (mean)
Time per request:       3.973 [ms] (mean, across all concurrent requests)
Transfer rate:          138.83 [Kbytes/sec] received

Connection Times (ms)
              min  mean[+/-sd] median   max
Connect:        0  157 669.5      0    3004
Processing:   113  434 316.3    436    4560
Waiting:      112  434 316.3    436    4560
Total:        113  592 730.9    439    5916

Percentage of the requests served within a certain time (ms)
  50%    439
  66%    447
  75%    457
  80%    466
  90%    502
  95%   3193
  98%   3382
  99%   3439
 100%   5916 (longest request)
<snip>
```

Profiling Concepts

- Diagnose a running system for bottlenecks
  - I/O
  - Memory
  - CPU
  - Operating System (e.g. file descriptor usage)
  - Network
- Look for the big bottlenecks; don't waste time over-optimizing for microseconds

Slow Query Log

- Enable in the *my.cnf* configuration file:

```
log_slow_queries=/var/lib/mysql/slow-queries.log # location of log file
long_query_time=2 # number of seconds for MySQL to consider it slow
log_long_format # log any query not using an index (full table scans)
```

- 5.1+ does not require a server restart
- Use mysqldumpslow program to parse

The EXPLAIN Command

- Simply append EXPLAIN before any SELECT statement
- Returns the execution plan chosen
- Each row in output is a set of information
  - A real schema table
  - A “virtual” table (a subquery in the FROM clause)
  - A subquery in the SELECT or WHERE clause
  - A UNIONed resultset

Example EXPLAIN output

```
mysql> EXPLAIN SELECT f.film_id, f.title, c.name
    -> FROM film f INNER JOIN film_category fc
    -> ON f.film_id=fc.film_id INNER JOIN category c
    -> ON fc.category_id=c.category_id WHERE f.title LIKE 'T%' \G
*************************** 1. row ***************************
  select_type: SIMPLE
        table: c
         type: ALL
possible_keys: PRIMARY
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 16
        Extra:
*************************** 2. row ***************************
  select_type: SIMPLE
        table: fc
         type: ref
possible_keys: PRIMARY,fk_film_category_category
          key: fk_film_category_category
      key_len: 1
          ref: sakila.c.category_id
         rows: 1
        Extra: Using index
*************************** 3. row ***************************
  select_type: SIMPLE
        table: f
         type: eq_ref
possible_keys: PRIMARY,idx_title
          key: PRIMARY
      key_len: 2
          ref: sakila.fc.film_id
         rows: 1
        Extra: Using where
```

An estimate of rows in this set

The “access strategy” chosen

The available indexes, and the one(s) chosen

A **covering index** is used

EXPLAIN Tips

- There is a **huge** difference between “index” in the type column and “Using index” in the Extra column
  - In the type column, it means a full index scan
  - In the Extra column, it means a covering index
- 5.0+ look for the index_merge optimization
  - Prior to 5.0, only one index can be used per table
    - Would have to use a UNION to achieve same results
  - 5.0+ if multiple indexes can be used, can use them

Index Merge Example (5.0+)

```
mysql> EXPLAIN SELECT * FROM rental
    -> WHERE rental_id IN (10,11,12)
    -> OR rental_date = '2006-02-01' \G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: rental
         type: index_merge
possible_keys: PRIMARY,rental_date
          key: rental_date,PRIMARY
      key_len: 8,4
          ref: NULL
         rows: 4
        Extra: Using sort_union(rental_date,PRIMARY);
Using where
1 row in set (0.04 sec)
```

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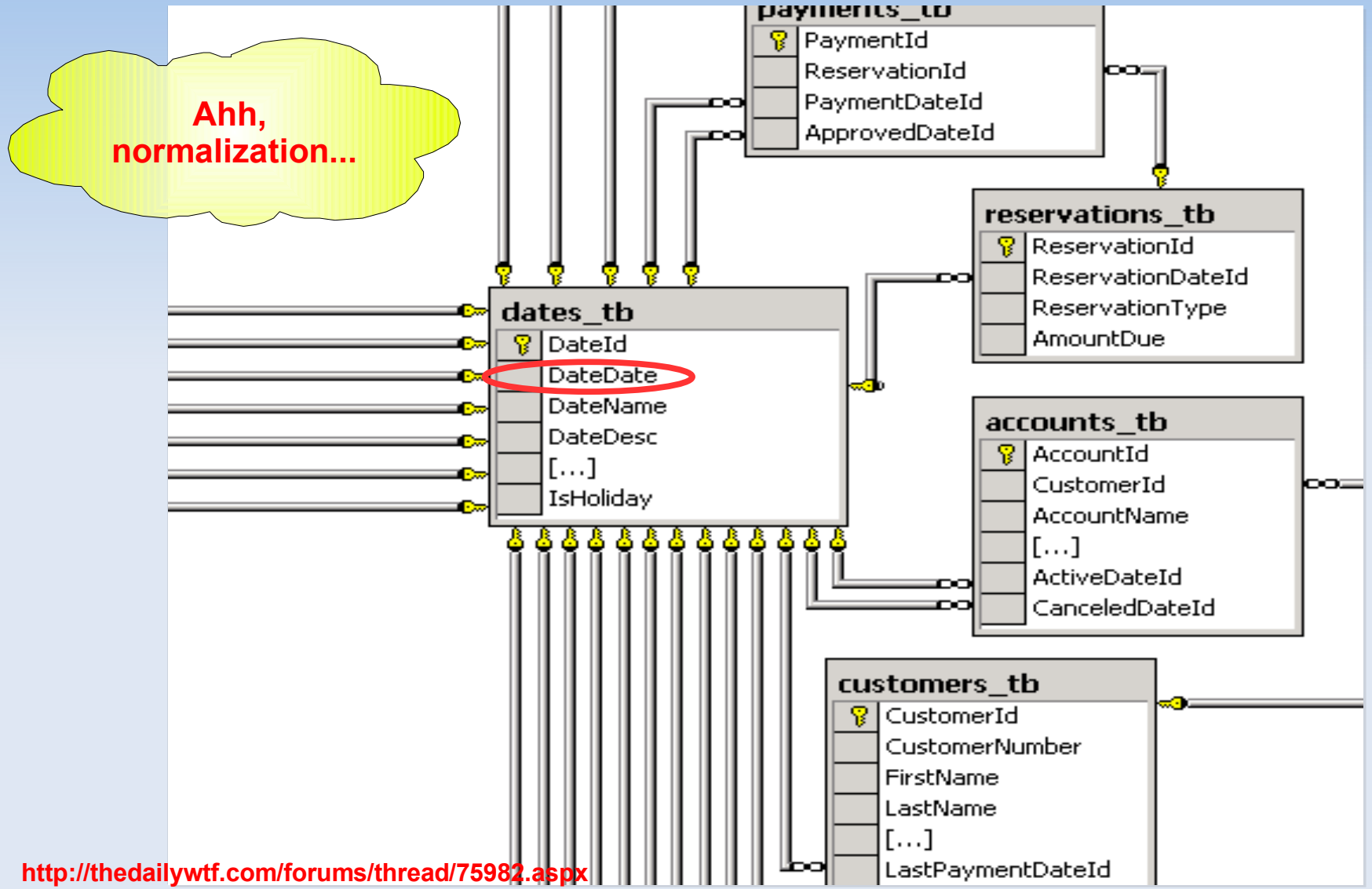
Schema and Index Strategies

Schema

- Poor schema is a great way to shoot yourself in the foot
- Use smallest data types possible (esp. InnoDB)
  - Do you *really* need that BIGINT?
- Smaller the field structure in table or index row, the more records can fit into a single page (so faster accesses!)
- Normalize first, then de-normalize only in extreme cases

Journey to the Center of the Database



http://thedailywtf.com/forums/thread/75982.aspx

MySQL

Horizontal Partitioning Example

```
CREATE TABLE Users (
  user_id INT NOT NULL AUTO_INCREMENT
, email VARCHAR(80) NOT NULL
, display_name VARCHAR(50) NOT NULL
, password CHAR(41) NOT NULL
, first_name VARCHAR(25) NOT NULL
, last_name VARCHAR(25) NOT NULL
, address VARCHAR(80) NOT NULL
, city VARCHAR(30) NOT NULL
, province CHAR(2) NOT NULL
, postcode CHAR(7) NOT NULL
, interests TEXT NULL
, bio TEXT NULL
, signature TEXT NULL
, skills TEXT NULL
, company TEXT NULL
, PRIMARY KEY (user_id)
, UNIQUE INDEX (email)
) ENGINE=InnoDB;
```

```
CREATE TABLE Users (
  user_id INT NOT NULL AUTO_INCREMENT
, email VARCHAR(80) NOT NULL
, display_name VARCHAR(50) NOT NULL
, password CHAR(41) NOT NULL
, PRIMARY KEY (user_id)
, UNIQUE INDEX (email)
) ENGINE=InnoDB;

CREATE TABLE UserExtra (
  user_id INT NOT NULL
, first_name VARCHAR(25) NOT NULL
, last_name VARCHAR(25) NOT NULL
, address VARCHAR(80) NOT NULL
, city VARCHAR(30) NOT NULL
, province CHAR(2) NOT NULL
, postcode CHAR(7) NOT NULL
, interests TEXT NULL
, bio TEXT NULL
, signature TEXT NULL
, skills TEXT NULL
, company TEXT NULL
, PRIMARY KEY (user_id)
) ENGINE=InnoDB;
```

When Horizontal Partitioning Makes Sense

- "Extra" columns are mostly NULL
- "Extra" columns are infrequently accessed
- When space in buffer pool is at a premium
  - Splitting the table allows main records to consume the buffer pages without the extra data taking up space in memory
  - Many more "main" records can fit into a single 16K InnoDB data page
- To use FULLTEXT on your text columns

Counter Table Example

```
CREATE TABLE Products (
  product_id INT NOT NULL AUTO_INCREMENT
, name VARCHAR(80) NOT NULL
, unit_cost DECIMAL(7,2) NOT NULL
, description TEXT NULL
, image_path TEXT NULL
, num_views INT UNSIGNED NOT NULL
, num_in_stock INT UNSIGNED NOT NULL
, num_on_order INT UNSIGNED NOT NULL
, PRIMARY KEY (product_id)
, INDEX (name(20))
) ENGINE=InnoDB; // Or MyISAM

// Getting a simple COUNT of products
// easy on MyISAM, terrible on InnoDB
SELECT COUNT(*)
FROM Products;
```

```
CREATE TABLE Products (
  product_id INT NOT NULL AUTO_INCREMENT
, name VARCHAR(80) NOT NULL
, unit_cost DECIMAL(7,2) NOT NULL
, description TEXT NULL
, image_path TEXT NULL
, PRIMARY KEY (product_id)
, INDEX (name(20))
) ENGINE=InnoDB; // Or MyISAM

CREATE TABLE ProductCounts (
  product_id INT NOT NULL
, num_views INT UNSIGNED NOT NULL
, num_in_stock INT UNSIGNED NOT NULL
, num_on_order INT UNSIGNED NOT NULL
, PRIMARY KEY (product_id)
) ENGINE=InnoDB;

CREATE TABLE ProductCountSummary (
  total_products INT UNSIGNED NOT NULL
) ENGINE=MEMORY;
```

When Counter Tables Make Sense

- Mixing static attributes with frequently **updated** fields in a single table?
  - Thrashing occurs with query cache. Each time an update occurs **on any record in the table**, all queries referencing the table are invalidated in the Query Cache
- Doing COUNT(*) with no WHERE on an indexed field on an **InnoDB** table?
  - Complications with versioning make full record counts very slow

Identifying Good Field Candidates for Indexes

- Good Selectivity (% distinct values in field)
- Used in WHERE? ON? GROUP BY? ORDER BY?
- How to determine selectivity of current indexes?
  - `SHOW INDEX FROM some_table`
    - Repeat as needed
  - `SELECT COUNT(DISTINCT some_field)/COUNT(*) FROM some_table`
    - Repeat as needed
  - or, use the INFORMATION_SCHEMA ...

INFORMATION_SCHEMA is your friend

TABLE_SCHEMA	TABLE_NAME	INDEX_NAME	COLUMN_NAME	SEQ_IN_INDEX	COLS_IN_INDEX	CARD	ROWS	SEL %
worklog	amendments	text	text	1	1	1	33794	0.00
planetmysql	entries	categories	categories	1	3	1	4171	0.02
planetmysql	entries	categories	title	2	3	1	4171	0.02
planetmysql	entries	categories	content	3	3	1	4171	0.02
sakila	inventory	idx_store_id_film_id	store_id	1	2	1	4673	0.02
sakila	rental	idx_fk_staff_id	staff_id	1	1	3	16291	0.02
worklog	tasks	title	title	1	2	1	3567	0.03
worklog	tasks	title	description	2	2	1	3567	0.03
sakila	payment	idx_fk_staff_id	staff_id	1	1	6	15422	0.04
mysqlforge	mw_recentchanges	rc_ip	rc_ip	1	1	2	996	0.20

Effects of Column Order in Indexes

```
mysql> EXPLAIN SELECT project, COUNT(*) as num_tags
    -> FROM Tag2Project
    -> GROUP BY project;
+-------------+-------+---------+-------------------------------------------------+
| table       | type  | key     | Extra                                           |
+-------------+-------+---------+-------------------------------------------------+
| Tag2Project | index | PRIMARY | Using index; Using temporary; Using filesort |
+-------------+-------+---------+-------------------------------------------------+

mysql> EXPLAIN SELECT tag, COUNT(*) as num_projects
    -> FROM Tag2Project
    -> GROUP BY tag;
+-------------+-------+---------+-------------+
| table       | type  | key     | Extra       |
+-------------+-------+---------+-------------+
| Tag2Project | index | PRIMARY | Using index |
+-------------+-------+---------+-------------+

mysql> CREATE INDEX project ON Tag2Project (project);
Query OK, 701 rows affected (0.01 sec)
Records: 701  Duplicates: 0  Warnings: 0

mysql> EXPLAIN SELECT project, COUNT(*) as num_tags
    -> FROM Tag2Project
    -> GROUP BY project;
+-------------+-------+---------+-------------+
| table       | type  | key     | Extra       |
+-------------+-------+---------+-------------+
| Tag2Project | index | project | Using index |
+-------------+-------+---------+-------------+
```

The Tag2Project Table:

```
CREATE TABLE Tag2Project (
tag INT UNSIGNED NOT NULL
, project INT UNSIGNED NOTNULL
, PRIMARY KEY (tag, project)
) ENGINE=MyISAM;
```


MySQL

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Black-belt SQL Coding

MySQL

SQL Coding Guidelines

- Change the way you think
  - SQL Programming != Procedural Programming
- No more “for” loop thinking
  - Instead, learn to think in “sets”
- KISS (Keep it Simple and Straightforward)
  - “Chunky” coding
  - If it looks too complex, break it down
- Be **consistent**
  - Helps you *and* your team

Thinking in Sets

"Show the maximum price that each product was sold, along with the product name for each product"

- Many programmers think:
  - OK, **for each** product, find the maximum price the product was sold and output that with the product's name (WRONG!)
- Think instead:
  - OK, I have **2 sets** of data here. One set of product names and another set of maximum sold prices

Not everything is as it seems...

```
mysql> EXPLAIN SELECT
    ->   p.*
    -> FROM payment p
    -> WHERE p.payment_date =
    -> ( SELECT MAX(payment_date)
    ->   FROM payment
    ->   WHERE customer_id=p.customer_id);
+--------------------+---------+------+---------------------------------+--------------+---------------+-------+-------------+
| select_type        | table   | type | possible_keys                   | key          | ref           | rows  | Extra       |
+--------------------+---------+------+---------------------------------+--------------+---------------+-------+-------------+
| PRIMARY            | p       | ALL  | NULL                            | NULL         | NULL          | 16451 | Using where |
| DEPENDENT SUBQUERY | payment | ref  | idx_fk_customer_id,payment_date | payment_date | p.customer_id |    12 | Using index |
+--------------------+---------+------+---------------------------------+--------------+---------------+-------+-------------+
3 rows in set (0.00 sec)
```

```
mysql> EXPLAIN SELECT
    ->   p.*
    -> FROM (
    ->  SELECT customer_id, MAX(payment_date) as last_order
    ->  FROM payment
    ->  GROUP BY customer_id
    -> ) AS last_orders
    -> INNER JOIN payment p
    -> ON p.customer_id = last_orders.customer_id
    -> AND p.payment_date = last_orders.last_order;
+-------------+------------+-------+---------------------------------+--------------------+-------------------------------+-------+
| select_type | table      | type  | possible_keys                   | key                | ref                           | rows  |
+-------------+------------+-------+---------------------------------+--------------------+-------------------------------+-------+
| PRIMARY     | <derived2> | ALL   | NULL                            | NULL               | NULL                          |   599 |
| PRIMARY     | p          | ref   | idx_fk_customer_id,payment_date | payment_date       | customer_id,last_order        |     1 |
| DERIVED     | payment    | index | NULL                            | idx_fk_customer_id | NULL                          | 16451 |
+-------------+------------+-------+---------------------------------+--------------------+-------------------------------+-------+
3 rows in set (0.10 sec)
```

...not what you expected?

```
mysql> SELECT
    ->   p.*
    -> FROM payment p
    -> WHERE p.payment_date =
    -> ( SELECT MAX(payment_date)
    ->   FROM payment
    ->   WHERE customer_id=p.customer_id);
+------------+-------------+----------+-----------+--------+---------------------+---------------------+
| payment_id | customer_id | staff_id | rental_id | amount | payment_date        | last_update         |
+------------+-------------+----------+-----------+--------+---------------------+---------------------+
<snip>
|      16049 |         599 |        2 |     15725 |   2.99 | 2005-08-23 11:25:00 | 2006-02-15 19:24:13 |
+------------+-------------+----------+-----------+--------+---------------------+---------------------+
623 rows in set (0.49 sec)
```

```
mysql> SELECT
    ->   p.*
    -> FROM (
    ->  SELECT customer_id, MAX(payment_date) as last_order
    ->  FROM payment
    ->  GROUP BY customer_id
    -> ) AS last_orders
    -> INNER JOIN payment p
    -> ON p.customer_id = last_orders.customer_id
    -> AND p.payment_date = last_orders.last_order;
+------------+-------------+----------+-----------+--------+---------------------+---------------------+
| payment_id | customer_id | staff_id | rental_id | amount | payment_date        | last_update         |
+------------+-------------+----------+-----------+--------+---------------------+---------------------+
<snip>
|      16049 |         599 |        2 |     15725 |   2.99 | 2005-08-23 11:25:00 | 2006-02-15 19:24:13 |
+------------+-------------+----------+-----------+--------+---------------------+---------------------+
623 rows in set (0.09 sec)
```

Isolate those Indexed Fields!

```
mysql> EXPLAIN SELECT * FROM film WHERE title LIKE 'Tr%'\G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: film
         type: range
possible_keys: idx_title
          key: idx_title
      key_len: 767
          ref: NULL
         rows: 15
        Extra: Using where
```

Nice. In the top query, we have a fast range access on the indexed field

```
mysql> EXPLAIN SELECT * FROM film WHERE LEFT(title,2) = 'Tr' \G
*************************** 1. row ***************************
           id: 1
  select_type: SIMPLE
        table: film
         type: ALL
possible_keys: NULL
          key: NULL
      key_len: NULL
          ref: NULL
         rows: 951
        Extra: Using where
```

Oops. In the bottom query, we have a slower full table scan because of the function operating on the indexed field (the LEFT() function)

A Very Common Isolated Index Field Problem

```
SELECT * FROM Orders
WHERE TO_DAYS(CURRENT_DATE())
- TO_DAYS(order_created) <= 7;
```

Not a good idea! Lots o' problems with this...

```
SELECT * FROM Orders
WHERE order_created
>= CURRENT_DATE() - INTERVAL 7 DAY;
```

Better... Now the index on order_created will be used at least. Still a problem, though...

```
SELECT * FROM Orders
WHERE order_created
>= '2007-02-11' - INTERVAL 7 DAY;
```

Best. Now the query cache can cache this query, and given no updates, only run it once a day...

Calculated Field Example

```
CREATE TABLE Customers (
  customer_id INT NOT NULL
, email VARCHAR(80) NOT NULL
// more fields
, PRIMARY KEY (customer_id)
, INDEX (email(40))
) ENGINE=InnoDB;

// Bad idea, can't use index
// on email field
SELECT *
FROM Customers
WHERE email LIKE '%.com';
```

```
// So, we enable fast searching on a reversed field
// value by inserting a calculated field
ALTER TABLE Customers
ADD COLUMN rv_email VARCHAR(80) NOT NULL;

// Now, we update the existing table values
UPDATE Customers SET rv_email = REVERSE(email);

// Then, we create an index on the new field
CREATE INDEX ix_rv_email ON Customers (rv_email);

// Then, we make a trigger to keep our data in sync
DELIMITER ;;
CREATE TRIGGER trg_bi_cust
BEFORE INSERT ON Customers
FOR EACH ROW BEGIN
 SET NEW.rv_email = REVERSE(NEW.email);
END ;;

// same trigger for BEFORE UPDATE...
// Then SELECT on the new field...
WHERE rv_email LIKE CONCAT(REVERSE('.com'), '%');
```

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Tuning Server Settings

SHOW STATUS and SHOW VARIABLES

- SHOW STATUS
  - Counter variables (lots of `em)
  - Count reads, writes, threads, etc.
- SHOW VARIABLES
  - Your configuration variables
- Both take a LIKE clause, for example:

```
mysql> SHOW STATUS LIKE 'Created_tmp%';
+-------------------------+-------+
| Variable_name           | Value |
+-------------------------+-------+
| Created_tmp_disk_tables | 499   |
| Created_tmp_files       | 5     |
| Created_tmp_tables      | 1933  |
+-------------------------+-------+
```

Server Variable Guidelines

- Be aware of what is *global* vs *per thread*
- Make small changes, then test
- Often provide a quick solution, but temporary
- Query Cache is not a panacea
- **key_buffer_size** != **innodb_buffer_pool_size**
- Remember mysql system database is MyISAM
- Memory is cheapest, fastest, easiest way to increase performance

MyISAM

- **key_buffer_size**
  - Main MyISAM key cache (blocks of size 1K)
  - Watch for **Key_blocks_unused** approaching 0
- **table_cache** (InnoDB too...)
  - Number of simultaneously open file descriptors
    - < 5.1 contains meta data about tables and file descriptor
    - >= 5.1 Split into table_open_cache
- **myisam_sort_buffer_size**
  - Building indexes, set this as high as possible

MyISAM

- Examine **Handler_read_rnd_next/Handler_read_rnd** for *average size of table scans*

```
mysql> SHOW STATUS LIKE 'Handler_read_rnd%';
+-----------------------+--------+
| Variable_name         | Value  |
+-----------------------+--------+
| Handler_read_rnd      | 2188   |
| Handler_read_rnd_next | 217247 |
+-----------------------+--------+
```

- Examine **Key_read_requests/Key_reads** for your *key_cache hit ratio*

```
mysql> SHOW STATUS LIKE 'Key_read%';
+-------------------+-------+
| Variable_name     | Value |
+-------------------+-------+
| Key_read_requests | 10063 |
| Key_reads         | 98    |
+-------------------+-------+
```

InnoDB

- **innodb_buffer_pool_size**
  - Main InnoDB cache for both data and index pages (16K page)
  - If you have InnoDB-only system, set to 60-80% of total memory
  - Watch for **Innodb_buffer_pool_pages_free** approaching 0
- **innodb_log_file_size**
  - Size of the actual log file
  - Set to 40-50% of **innodb_buffer_pool_size**

InnoDB (cont'd)

- **innodb_log_buffer_size**
  - Size of double-write log buffer
  - Set < 16M (recommend 1M to 8M)
- **innodb_flush_method**
  - Determines how InnoDB flushes data and logs
  - defaults to fsync()
  - If getting lots of **Innodb_data_pending_fsyncs**
    - Consider O_DIRECT (Linux only)
  - Other ideas
  - Get a battery-backed disk controller with a write-back cache
  - Set **innodb_flush_log_at_trx_commit**=2 (Risky)

Examining Hit Rates (InnoDB and Query Cache)

- Examine **Innodb_buffer_pool_reads** vs **Innodb_buffer_pool_read_requests** for the *cache hit ratio*

```
mysql> SHOW STATUS LIKE 'Innodb_buffer_pool_read%';
+---------------------------------+---------+
| Variable_name                   | Value   |
+---------------------------------+---------+
| Innodb_buffer_pool_read_requests | 5415365 |
| Innodb_buffer_pool_reads        | 34260   |
+---------------------------------+---------+
```

```
mysql> SHOW STATUS LIKE 'Qc%';
+-------------------------+-------+
| Variable_name           | Value |
+-------------------------+-------+
| Qcache_free_blocks      | 1     |
| Qcache_hits             | 6     |
| Qcache_inserts          | 12    |
| Qcache_not_cached       | 41    |
| Qcache_lowmem_prunes    | 0     |
| Questions               | 241   |
+-------------------------+-------+
```

- Examine **Qcache_hits/Questions** for the *query cache hit ratio*
- Ensure **Qcache_lowmem_prunes** is low
- Ensure **Qcache_free_blocks** > 0

Further Reading

- ***Optimizing Linux Performance***
  - Philip Ezolt, HP Press
- **http://www.mysqlperformanceblog.com/**
  - Peter Zaitsev
- **http://xaprb.com**
  - Baron Schwartz
- **http://planetmysql.org**
  - Planet MySQL
- ***Advanced PHP Programming***
  - George Schlossnagle, Developer's Library

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Thanks!

Come to the Users Conference in April!
http://mysqlconf.com