A Benchmark for Non-Blocking Schema Transformations

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DATA 2015

Why change the structure of data?

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Logical changes:

- Add or remove columns
- Add constraints
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- Use surrogate keys instead of natural keys
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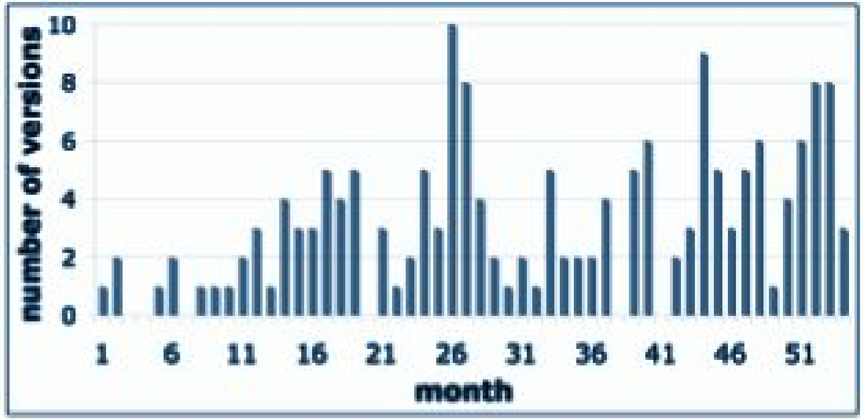
Improve performance:

- Add indices
- Precompute aggregates
- Change normalization
- ...

What is the problem?

WikiMedia schema revisions:



Source: http://yellowstone.cs.ucla.edu/schema-evolution/index.php/Schema_Evolution_Benchmark

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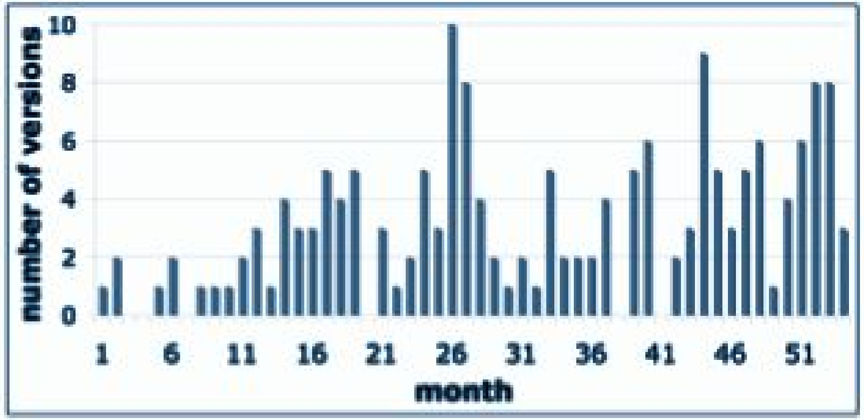

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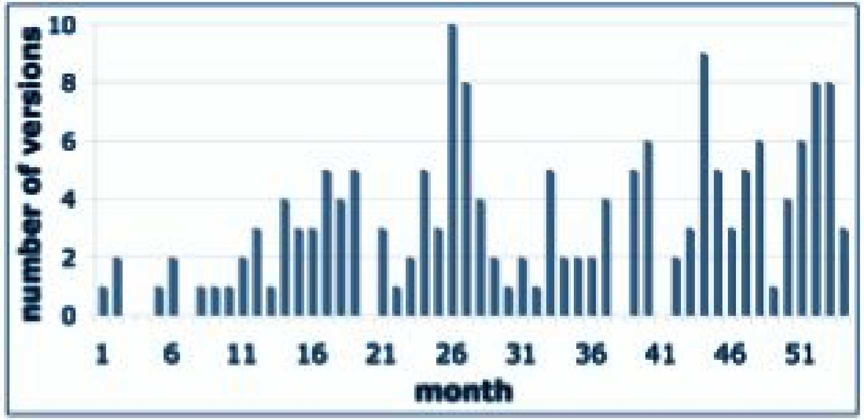

- 90% require a write lock.
- Largest took 22 hours to complete for wikipedia.

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The DBMS should provide a solution!

Support for Online Schema Changes

DBMS support:

- PostgreSQL: Partial Instantaneous DDL
- MySQL: Partial Online DDL
- Oracle: Parallel copy

Third party tools (for MySQL):

- pt-online-schema-change
- oak-online-alter-table
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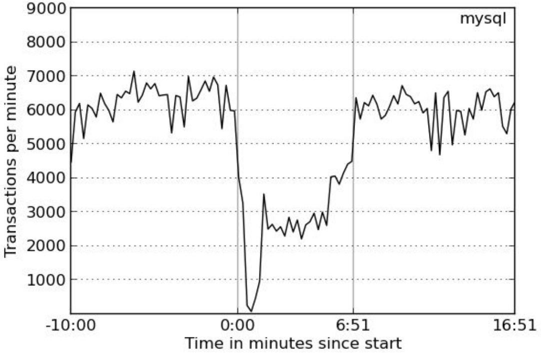
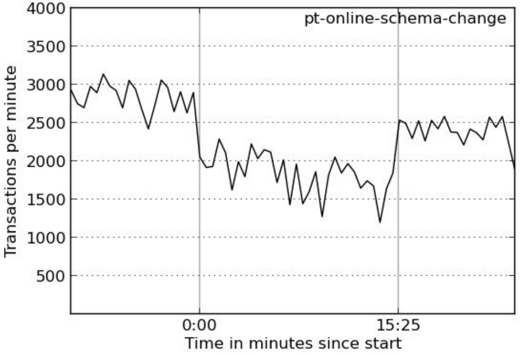
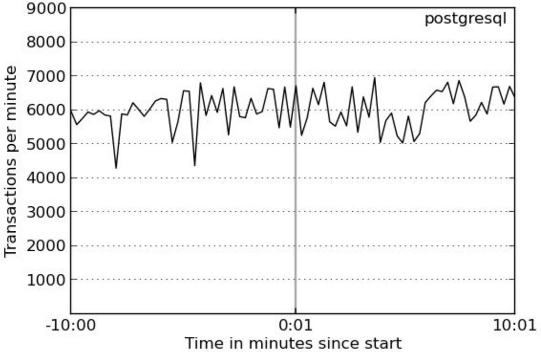
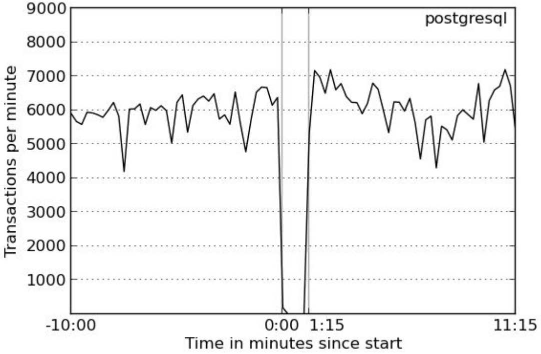
To what degree do these solutions work?

Benchmark: Adding a Column

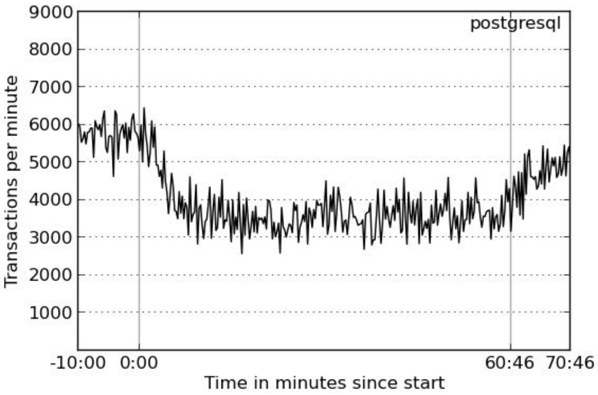


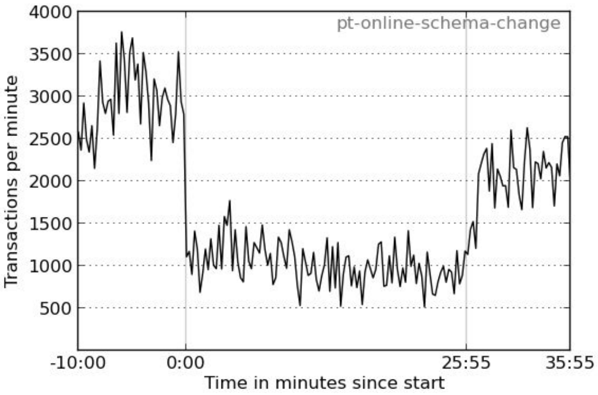


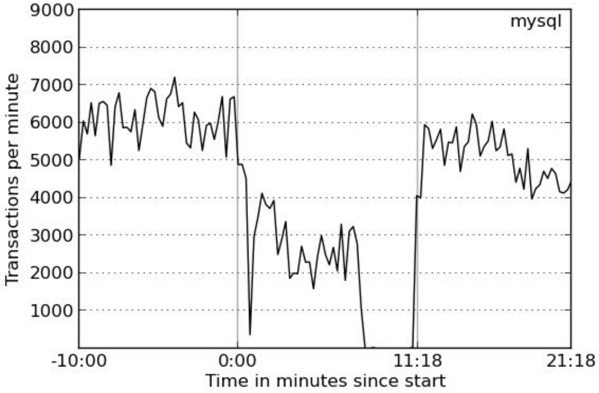




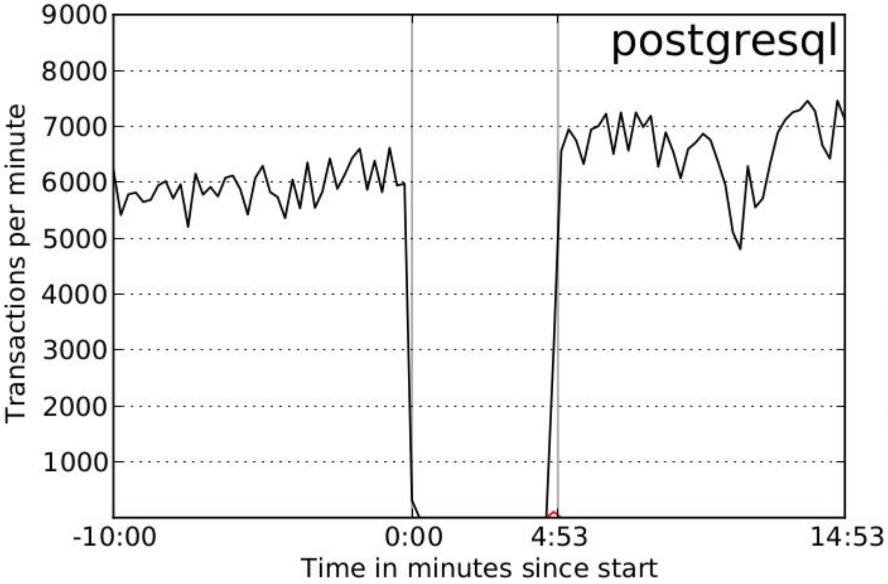
Benchmark: Creating an Index

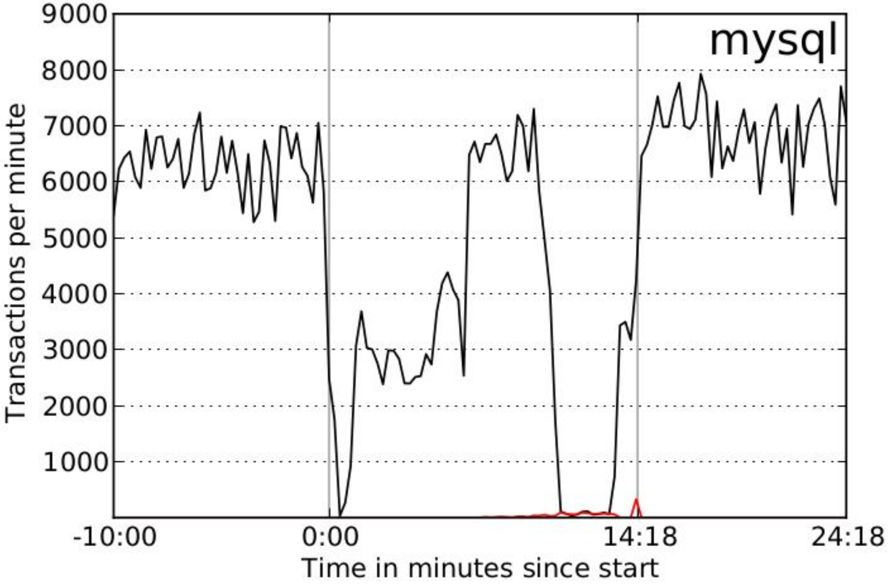






Complex Transformations





No support by third party tools

Current Situation

- Mixed results for basic (DDL) transformations:
    - Columns
    - Indices
    - Constraints
    - Data transformations

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  - Columns
  - Indices
  - Constraints
  - Data transformations

- Support for complex online transformations is mostly absent:
  - Change a primary key
  - Splitting and merging of tables
  - Changing the cardinality of a relationship
  - ...

Contributions

- Criteria for evaluating online schema change mechanisms in general, and for the relational model in particular.
- A concrete benchmark based on TPC-C to:
  - Compare existing solutions
  - Challenge the DB community to find solutions

Contributions

- Criteria for evaluating online schema change mechanisms in general, and for the relational model in particular.

Criteria for Online Transformations

We have defined criteria for:

- Functionality of OST
- Performance of OST

We define:

- Ideal behaviour
- Acceptable behaviour

Based on characteristics of state of the art solutions.

Functional Criteria

A mechanism for schema transformations should:

- Allow simple and complex transformations
- Provide data in new schema upon commit
- Satisfy the ACID properties
- Be declarative
- Support online upgrading of database applications

Performance Characteristics

Impact on concurrent transactions:

- Blocking
- Aborts
- Slowdown

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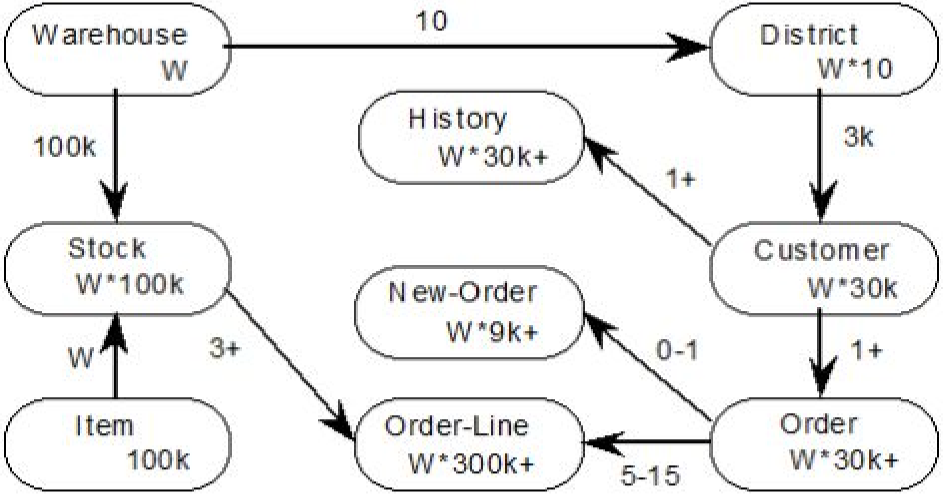
Performance of schema transformations:

- No aborts
- Time to commit

Benchmark

TPC-C



New order

Payment

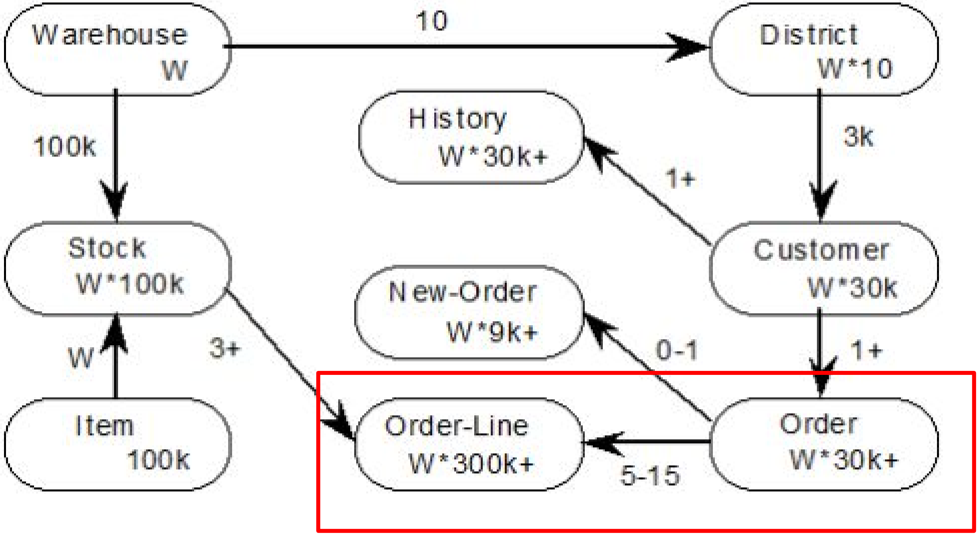
Order status

Delivery

Stock level

Benchmark

TPC-C



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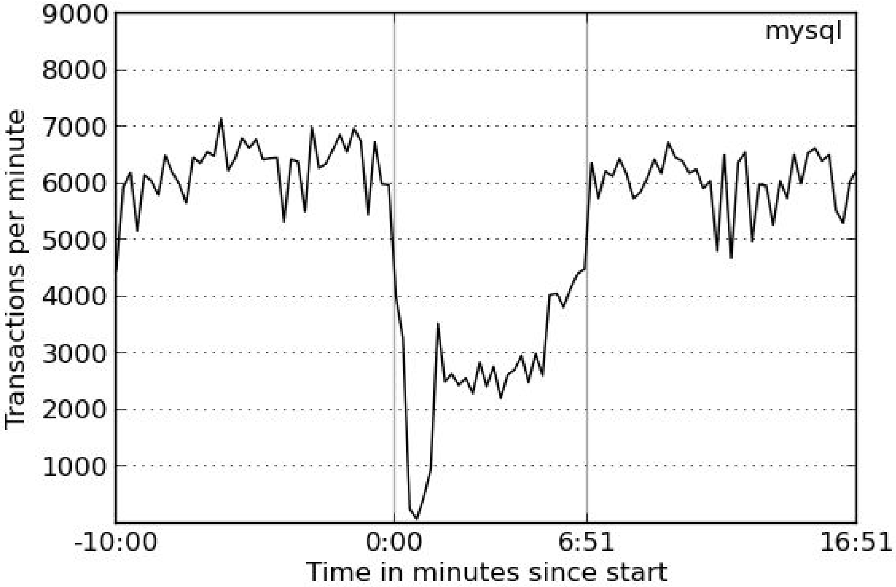
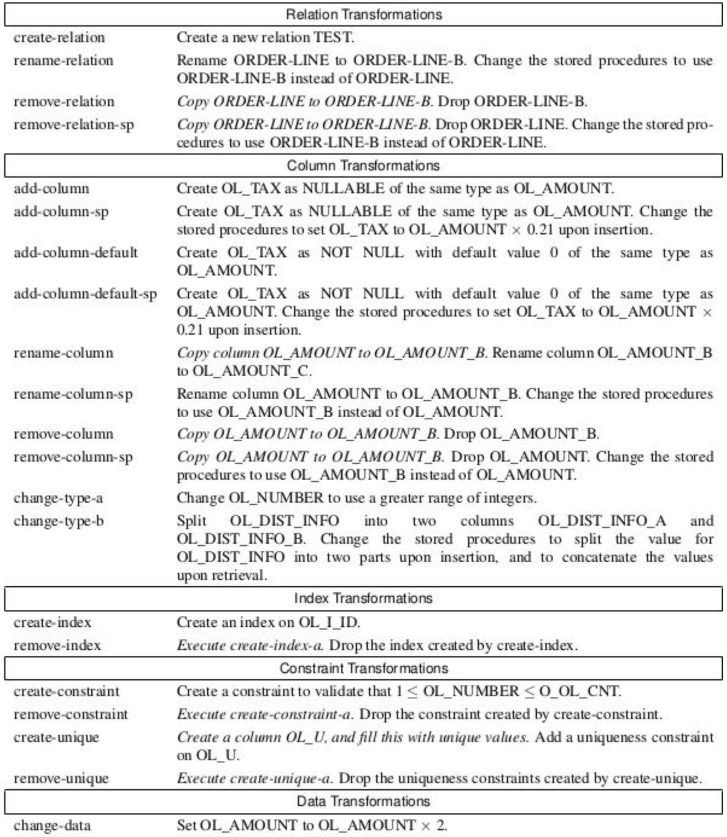
Benchmark Process

- Setup database
- Start TPC-C
- Intro period
- Transform:
    - Schema
    - Stored procedures
- Outro period
- Stop TPC-C



Benchmark Cases



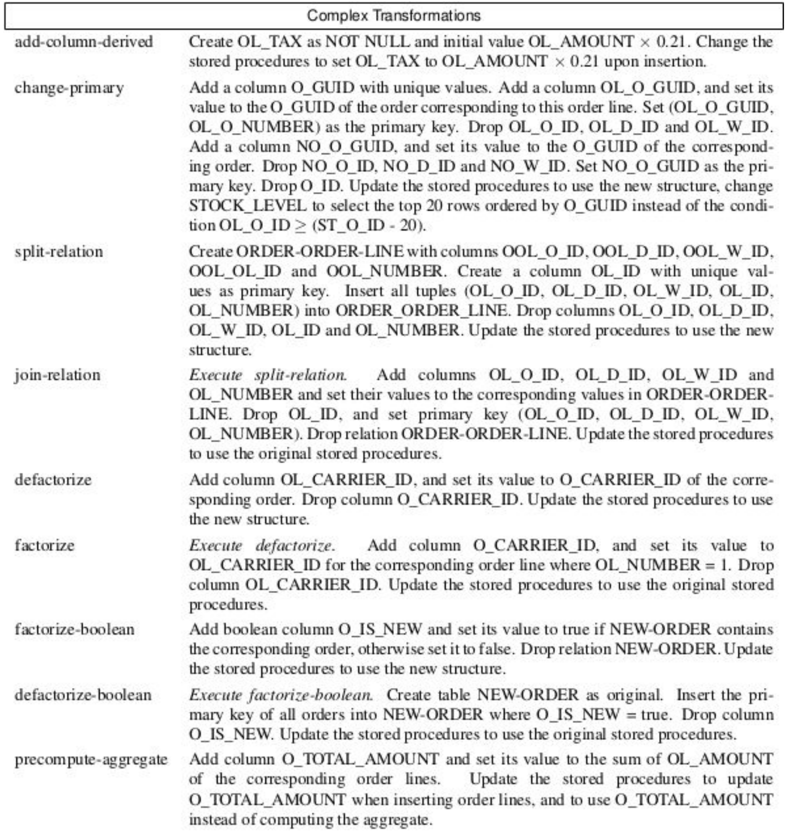
Relation Transformations	
create-relation	Create a new relation TEST.
rename-relation	Rename ORDER-LINE to ORDER-LINE-B. Change the stored procedures to use ORDER-LINE-B instead of ORDER-LINE.
remove-relation	*Copy ORDER-LINE to ORDER-LINE-B.* Drop ORDER-LINE-B.
remove-relation-sp	*Copy ORDER-LINE to ORDER-LINE-B.* Drop ORDER-LINE. Change the stored procedures to use ORDER-LINE-B instead of ORDER-LINE.

Column Transformations	
add-column	Create OL_TAX as NULLABLE of the same type as OL_AMOUNT.
add-column-sp	Create OL_TAX as NULLABLE of the same type as OL_AMOUNT. Change the stored procedures to set OL_TAX to OL_AMOUNT × 0.21 upon insertion.
add-column-default	Create OL_TAX as NOT NULL with default value 0 of the same type as OL_AMOUNT.
add-column-default-sp	Create OL_TAX as NOT NULL with default value 0 of the same type as OL_AMOUNT. Change the stored procedures to set OL_TAX to OL_AMOUNT × 0.21 upon insertion.
rename-column	*Copy column OL_AMOUNT to OL_AMOUNT_B.* Rename column OL_AMOUNT_B to OL_AMOUNT_C.
rename-column-sp	Rename column OL_AMOUNT to OL_AMOUNT_B. Change the stored procedures to use OL_AMOUNT_B instead of OL_AMOUNT.
remove-column	*Copy OL_AMOUNT to OL_AMOUNT_B.* Drop OL_AMOUNT_B.
remove-column-sp	*Copy OL_AMOUNT to OL_AMOUNT_B.* Drop OL_AMOUNT. Change the stored procedures to use OL_AMOUNT_B instead of OL_AMOUNT.
change-type-a	Change OL_NUMBER to use a greater range of integers.
change-type-b	Split OL_DIST_INFO into two columns OL_DIST_INFO_A and OL_DIST_INFO_B. Change the stored procedures to split the value for OL_DIST_INFO into two parts upon insertion, and to concatenate the values upon retrieval.

Index Transformations	
create-index	Create an index on OL_I_ID.
remove-index	*Execute create-index-a.* Drop the index created by create-index.

Constraint Transformations	
create-constraint	Create a constraint to validate that 1 ≤ OL_NUMBER ≤ O_OL_CNT.
remove-constraint	*Execute create-constraint-a.* Drop the constraint created by create-constraint.
create-unique	*Create a column OL_U, and fill this with unique values.* Add a uniqueness constraint on OL_U.
remove-unique	*Execute create-unique-a.* Drop the uniqueness constraints created by create-unique.

Data Transformations	
change-data	Set OL_AMOUNT to OL_AMOUNT × 2.



Complex Transformations	
add-column-derived	Create OL_TAX as NOT NULL and initial value OL_AMOUNT × 0.21. Change the stored procedures to set OL_TAX to OL_AMOUNT × 0.21 upon insertion.
change-primary	Add a column O_GUID with unique values. Add a column OL_O_GUID, and set its value to the O_GUID of the order corresponding to this order line. Set (OL_O_GUID, OL_O_NUMBER) as the primary key. Drop OL_O_ID, OL_D_ID and OL_W_ID. Add a column NO_O_GUID, and set its value to the O_GUID of the corresponding order. Drop NO_O_ID, NO_D_ID and NO_W_ID. Set NO_O_GUID as the primary key. Drop O_ID. Update the stored procedures to use the new structure, change STOCK_LEVEL to select the top 20 rows ordered by O_GUID instead of the condition OL_O_ID ≥ (ST_O_ID - 20).
split-relation	Create ORDER-ORDER-LINE with columns OOL_O_ID, OOL_D_ID, OOL_W_ID, OOL_OL_ID and OOL_NUMBER. Create a column OL_ID with unique values as primary key. Insert all tuples (OL_O_ID, OL_D_ID, OL_W_ID, OL_ID, OL_NUMBER) into ORDER_ORDER_LINE. Drop columns OL_O_ID, OL_D_ID, OL_W_ID, OL_ID and OL_NUMBER. Update the stored procedures to use the new structure.
join-relation	*Execute split-relation.* Add columns OL_O_ID, OL_D_ID, OL_W_ID and OL_NUMBER and set their values to the corresponding values in ORDER-ORDER-LINE. Drop OL_ID, and set primary key (OL_O_ID, OL_D_ID, OL_W_ID, OL_NUMBER). Drop relation ORDER-ORDER-LINE. Update the stored procedures to use the original stored procedures.
defactorize	Add column OL_CARRIER_ID, and set its value to O_CARRIER_ID of the corresponding order. Drop column O_CARRIER_ID. Update the stored procedures to use the new structure.
factorize	*Execute defactorize.* Add column O_CARRIER_ID, and set its value to OL_CARRIER_ID for the corresponding order line where OL_NUMBER = 1. Drop column OL_CARRIER_ID. Update the stored procedures to use the original stored procedures.
factorize-boolean	Add boolean column O_IS_NEW and set its value to true if NEW-ORDER contains the corresponding order, otherwise set it to false. Drop relation NEW-ORDER. Update the stored procedures to use the new structure.
defactorize-boolean	*Execute factorize-boolean.* Create table NEW-ORDER as original. Insert the primary key of all orders into NEW-ORDER where O_IS_NEW = true. Drop column O_IS_NEW. Update the stored procedures to use the original stored procedures.
precompute-aggregate	Add column O_TOTAL_AMOUNT and set its value to the sum of OL_AMOUNT of the corresponding order lines. Update the stored procedures to update O_TOTAL_AMOUNT when inserting order lines, and to use O_TOTAL_AMOUNT instead of computing the aggregate.

Implementation

Benchmark scripts available for:

- MySQL
- PostgreSQL
- Oracle (partially implemented)
- pt-online-schema-change (only basic cases)

Based on the HammerDB TPC-C implementation.

Conclusion

- Criteria for online schema changes:
  - Clarify the problem of OST
  - Identify ideal characteristics of a solution
- We have developed a benchmark to:
  - Show the extend of the problem
  - Compare performance of solutions
  - Challenge the DB community to find solutions for:
    - Better support for basic transformations
    - Support for complex transformations

For more info

Read the paper:

- A Benchmark for Non-blocking Schema Transformations

Download the benchmark implementations:

- http://wwwhome.ewi.utwente.nl/~weversl2/?page=ost

ADBIS 2015 paper:

- Analysis of the Blocking Behaviour of Schema Transformations in Relational Database Systems