Validation in Optimistic Concurrency Control

ACM SIGMOD 2015 Programming Contest

Alexey Karyakin (*Crisis*), a2karyak@uwaterloo.ca

UNIVERSITY OF WATERLOO
FACULTY OF MATHEMATICS
David R. Cheriton School
of Computer Science

Task

- Compute a set of ***validations***, each producing a boolean
- A validation is a disjunction of ***queries*** and evaluated over a range of transactions
- A query is a conjunction of ***predicates*** over table records
- A predicate is a comparison ***operation*** (=, !=, <, <=, >, >=) of a table column value against a constant

Mathematical Formulation

database

number of queries in validation *v*

number of predicates in query *v,q*

constant of predicate *v,q,p*

$$validation_v(d) = \sum_{r=from_v}^{to_v} \sum_{q=0}^{|Q_v|-1} \prod_{p=0}^{|P_{v,q}|-1} op_{v,q,p}\left(d_{rel_{v,q},r,col_{v,q,p}}, val_{v,q,p}\right)$$

transaction range

operation of predicate *v,q,p*

column of predicate *v,q,p*

table of predicate *v,q,p*

$\sum$ logical OR

$\prod$ logical AND

Strategy

- Analyze data statistics
- Come up with a reasonable algorithm
- Parallelize to multiple threads
- **Win!**

Statistics

- Tables and columns are used highly non-uniformly!
- Selectivity of equality 1e-6 for most columns
- Some columns have many duplicates and low selectivity, can wreck hash table access
- Probability of query match: ~1e-3
- Probability of validation match: ~4%
- Since tiny number of queries match, most work is spent in evaluating non-matching predicates

Query Plans

To accommodate highly varying predicate selectivity, two query execution strategies:

- Index lookups for high selectivity predicates
- Full scans for low selectivity predicates
- Pretty much like in a DBMS
- Plan selection depends on column selectivity (number of unique values)

Index Lookups

- Hash table w/o collision resolution
- All historic values with the same hash value are linked
- No distinction between collisions and older values
- Dynamically-expanding hash table
- Validation is required

Scans

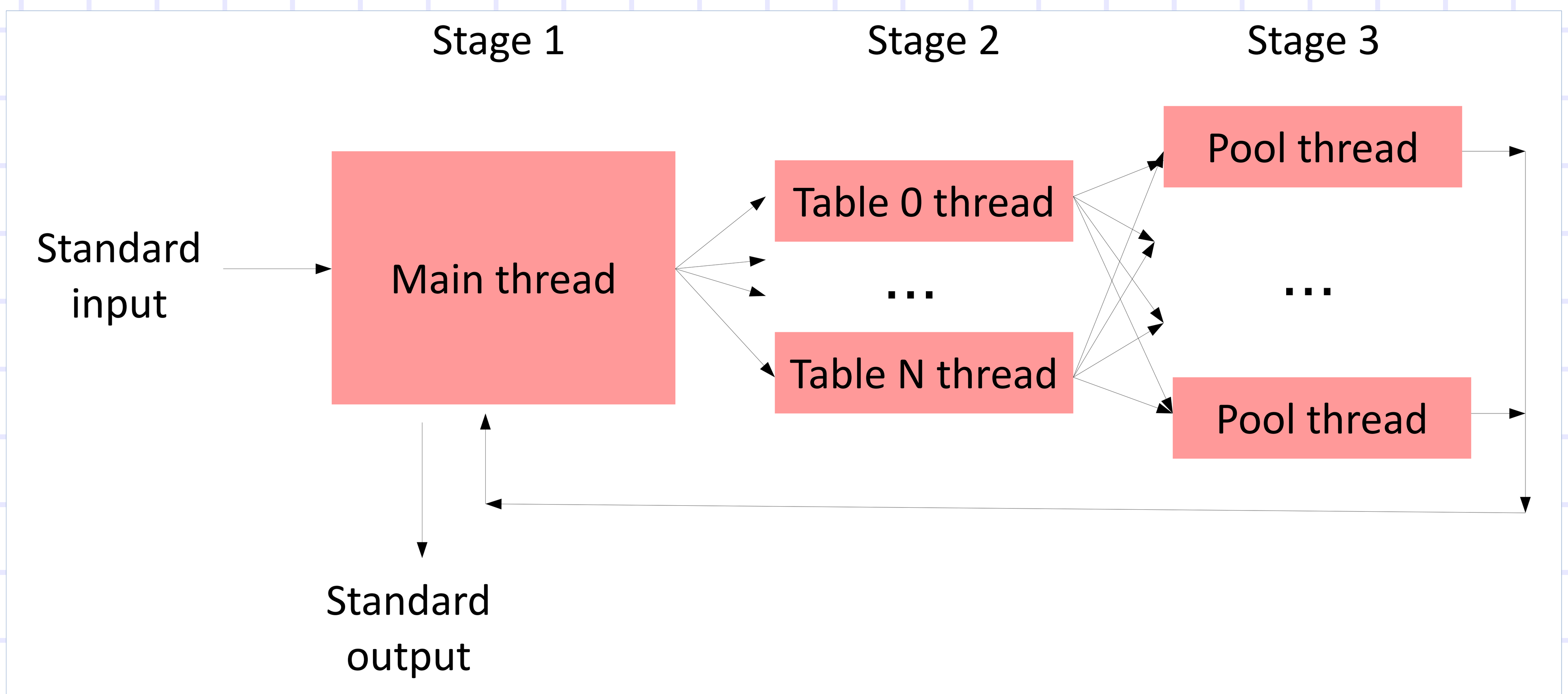
- Typically, used for queries w/o equality
- All transaction records are scanned backwards starting from the most recent
- Non-equality scans are accelerated with “aggregate records” for every N transaction, storing min and max for each column

Data Structures and Memory Allocation

- Primary key is stored in a B-tree (STX)
- Log-oriented storage for transaction records. New records are only appended and old records are purged lazily
- Link fields for index traversal are embedded into records

Three-Stage Multithreading

- Stage 1 (single thread): input parsing and distribution between tables
- Stage 2 (thread per table): building transaction history and primary key, initial stage of query evaluation
- Stage 3 (many threads): final evaluation over immutable input: following index links, scanning record ranges
- Unfortunately, due to high skew, degree of parallelism was low (~3)



Final Remarks

- C++ 11, ~2200 loc, excluding third-party code
- Final performance was limited by cache misses (mostly by index lookups)
- Technical implementation details are as important as algorithms

Third-Party Code Used

- STX B-tree (primary key): https://panthema.net/2007/stx-btree/
- Boost intrusive lists (work scheduler for multiple threads).