Resource Sharing in Continuous Sliding-Window Aggregation

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Motivation

- Large number of concurrent continuous queries
  - Publish-subscribe systems
- Handling each query separately
  - Inefficient
- Resource sharing among queries
  - Computation
  - Memory
  - Disk bandwidth

Motivation

- Operator level sharing
  - A single generic operator handling several queries
  - Previous work
    - Filters (stateless)
  - This paper
    - Aggregation over sliding windows
      - Each operator maintains state

Background

- Sliding windows
  - Used to solve problems with *unbounded* streams
  - window size
    - time interval (time-based)
    - number of tuples (tuple-based)
- Suffix windows
  - More recent data
- Non-suffix (historical) windows

Background

- Aggregation over a sliding window (ASW)
- Aggregations on substreams
  - Similar to GROUP BY
- Substream filters(SSF)
  - Similar to HAVING

Output Model

- ASW output updated
  - actively
    - as window slides
    - using some interval
  - Upon request
    - Lookup Model
    - considered in this paper

Cost Parameters

- 3 parameters
  - ***Space*** (memory) for maintaining state
  - ***Time*** to compute answer (lookup time)
  - ***Update time*** when a new tuple arrives
- Space-Update-Lookup Tradeoff
  - partial answer computation at update time
  - Compute final answers using partial results at lookup time

Resource Sharing

- In this work sharing is possible among operators
  - Over the same streams
  - Of the same type
  - Only different in their sliding window specification
- QUANTILE is an exception
  - Quantile parameter can also be different

ASW Operators

Agg. Functions

- Aggregation Functions
  - Distributive
    - $f(X_1)$ and $f(X_2) \Rightarrow f(X_1 \cup X_2)$
    - SUN, COUNT, MAX, MIN
  - Algebraic
    - There exists a synoptic function *g* such that
      - $g(X) \Rightarrow f(X)$
      - *g* is distributive
    - *AVG*
  - Holistic
    - Not algebraic
      - QUANTILE

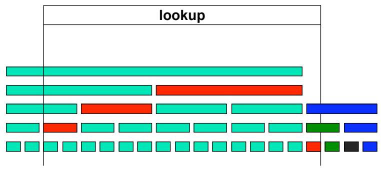
Algorithms

- Distributive or algebraic
  - *Base Intervals (B-INT)*
  - *Landmark Intervals (L-INT)*
- Results are precomputed and stored for some intervals
- Final answer for other intervals calculated using precomputed results

Base Intervals (B-INT)

- Base intervals
  - $(2^l\, i + 1,\ 2^l\, (i+1))$ for some i
- Active intervals
  - Intervals to the right of the beginning of the earliest window

B-INT



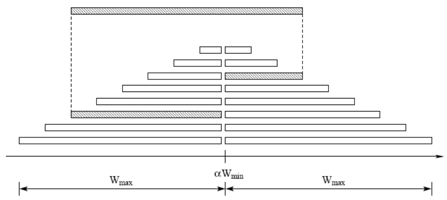
B-INT Costs

- Space
  - $O(N_{max})$
- Update (amortized)
  - $O(1)$
- Lookup (worst case)
  - $O(\log W)$

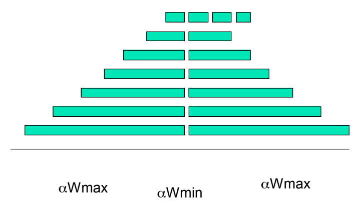
Landmark Intervals (L-INT)

- W_{min} and W_{max}
- Landmark intervals
  - $(\alpha W_{min}, \alpha W_{min} + d)$
  - $(\alpha W_{min} - d, \alpha W_{min} - 1)$
  - $d < W_{max}$

L-INT Lookup



L-INT Update



L-INT Costs

- W_{min} and W_{max} should be close to equal
- Space
  - $O(N_{max})$
- Update (amortized)
  - O(1)
- Lookup (worst case)
  - O(1)

PSoup

- Proposed by Chandrasekharan and Frankiln
- Uses an augmented *n*-ary search tree
  - Leaves are tuples
  - Internal nodes store the value of agg. Function for its descendents
- Update
  - O(log N_{max})
- Lookup
  - O(log N_{max})

QUANTILES

- Consider a bag of *N* elements
- QUANTILE (ϕ) = element at position ϕN in the sorted sequence of elements
- B-INT-QNT
  - Based on B-INT
  - Store a sorted array of elements for each base interval
  - Compute QUANTILE using the sorted arrays

SSF Operators

Sharing in SSF

- sharing among SSF operators that differ only in
  - Window specification
  - Range predicate

Simple Approach

- Simple Approach
  - For each substream
    - process ASW suboperations using one of the ASW sharing algorithms
    - Lookup cost depends on the size of key attribute domain |K|
- More efficient approaches
  - For certain comb. of window type and functions

CI-COUNT

- Used for function COUNT on substreams when range conditions are *one sided*
- Produces approximate answers

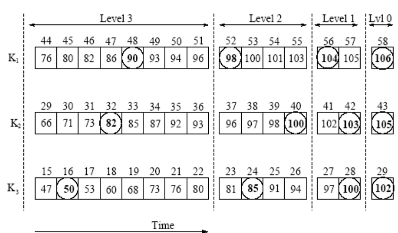
CI COUNT

- The following are equivalent
  - Look for substreams that have received more than ***v*** elements in the last ***T*** time units
  - Look for substreams for which the v^{th} element form the end has timestamp greater than τ-T

CI_COUNT

- Maintain an index over the timestamps of the v^{th} element from the end of all substreams
- Instead of maintaining an index for each *v* value, maintain an index for each *level*
- All *v* values such that *log v = l* share the same index

CI COUNT Example



CI-COUNT Costs

- Space
  - $O(|K| \log N_{max})$
- Update (amortized)
  - $O(\log |K|)$
- Lookup
  - $O(|K_o|)$

Comments

- The space and execution costs of algorithms are good
- Algorithms are easy to implement
- But no proof of optimality