Present Tense

Challenges and Trade-offs in Building a Web-scale Real-time Analytics System

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Problem

Collect, index, and query trillions of high-dimensionality records with seconds of latency for ingestion and response.

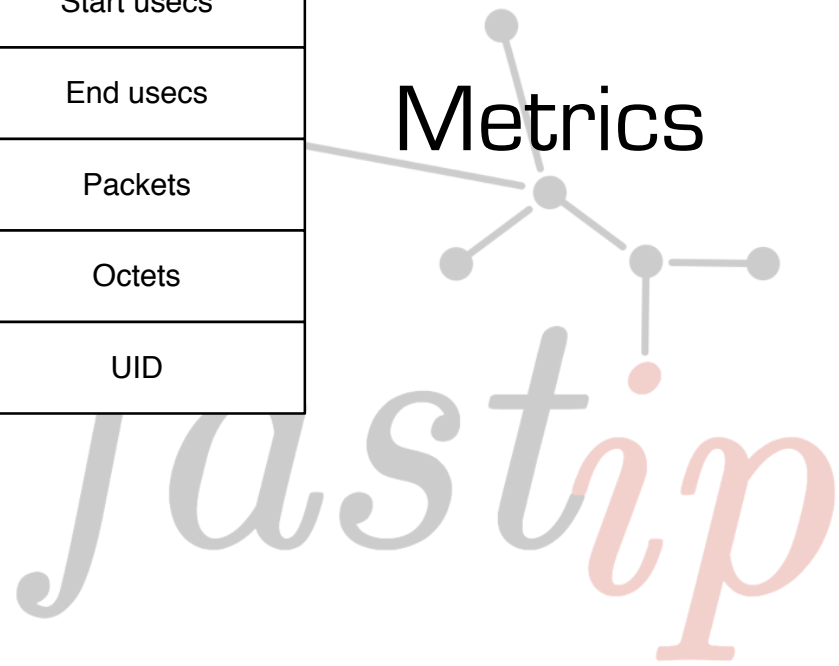
A (Partial) Record

Dimensions

Src MAC
Dst MAC
Src IPv4 Addr
Dst IPv4 Addr
Protocol
Src Transport Port
Dst Transport Port
Src IPv4 Lat
Src IPv4 Long
Dst IPv4 Lat
Dst IPv4 Long

Start usecs
End usecs
Packets
Octets
UID

Metrics



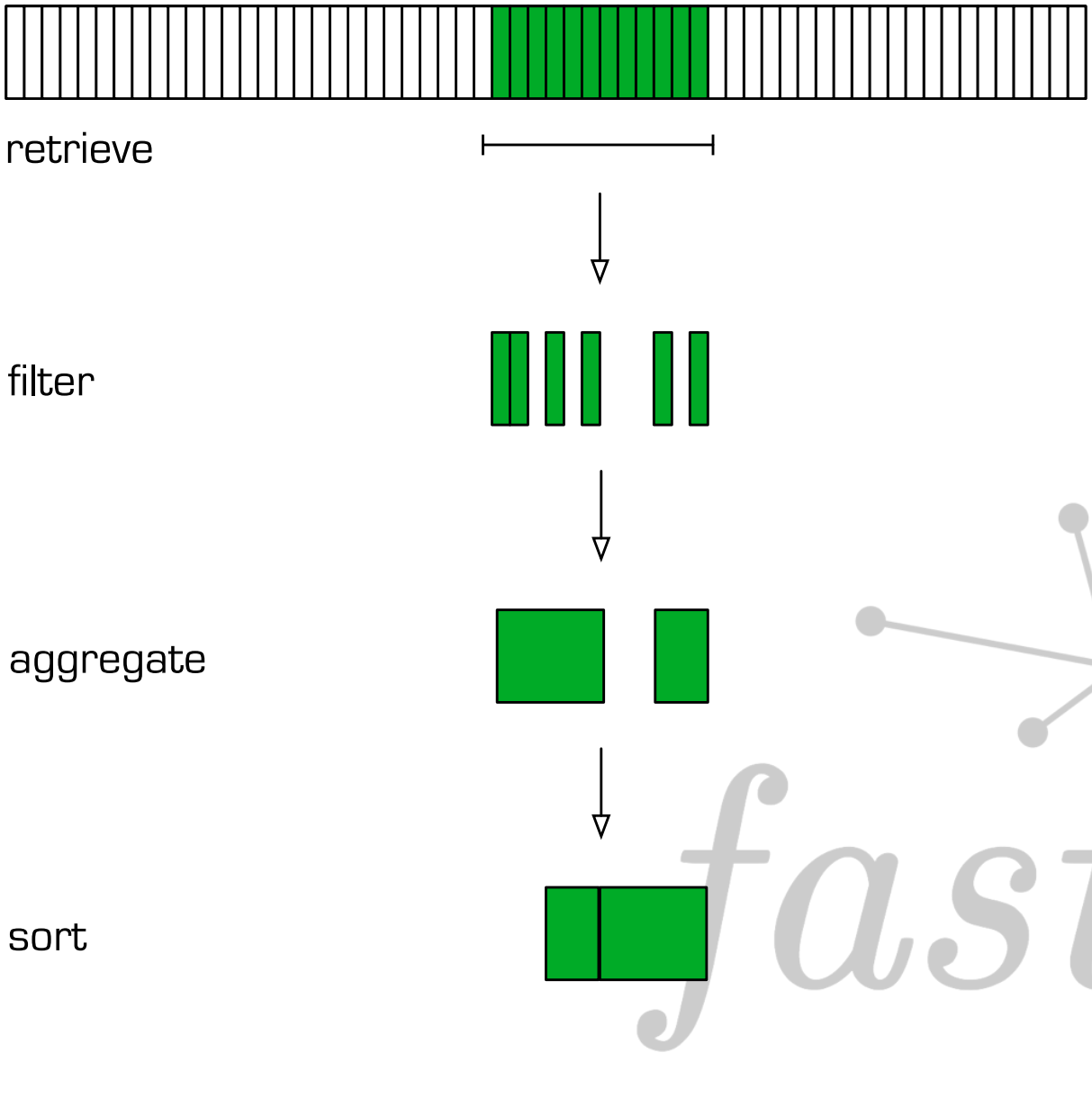
Why Is This Hard?

- **All our data is multi-dimensional – and we retain that dimensionality throughout.**
- 2-D systems (1 dimension + time) are simpler, but there is significant information loss with the dimensionality loss.
- Aggregation is loss of dimensionality.

First Attempt

- **MAXIMIZE SIMPLICITY.**
- Insert records into HBase.
- Retrieve all records in time range, then filter, aggregate, sort.

- Similar to OpenTSDB approach.

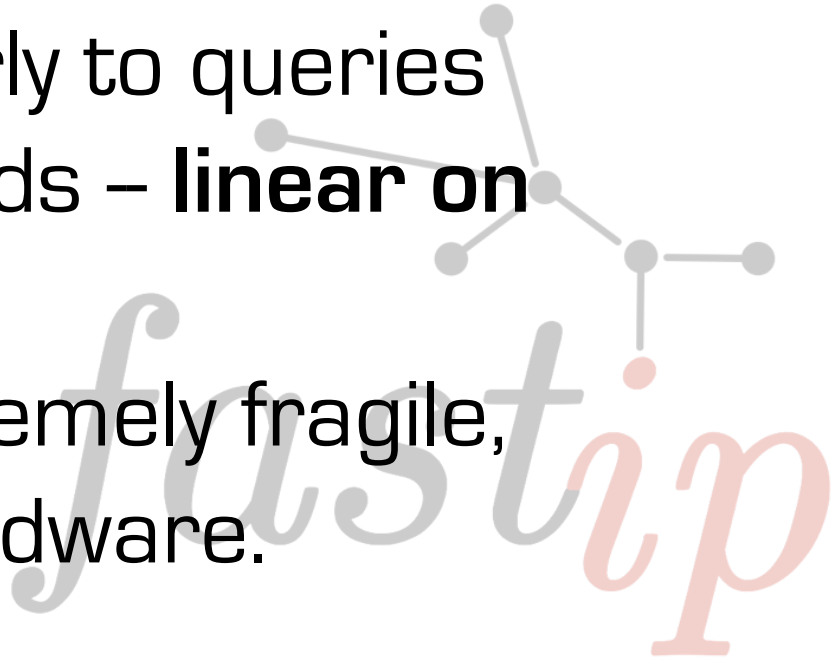

retrieve
filter
aggregate
sort

Apply Load

First Failure

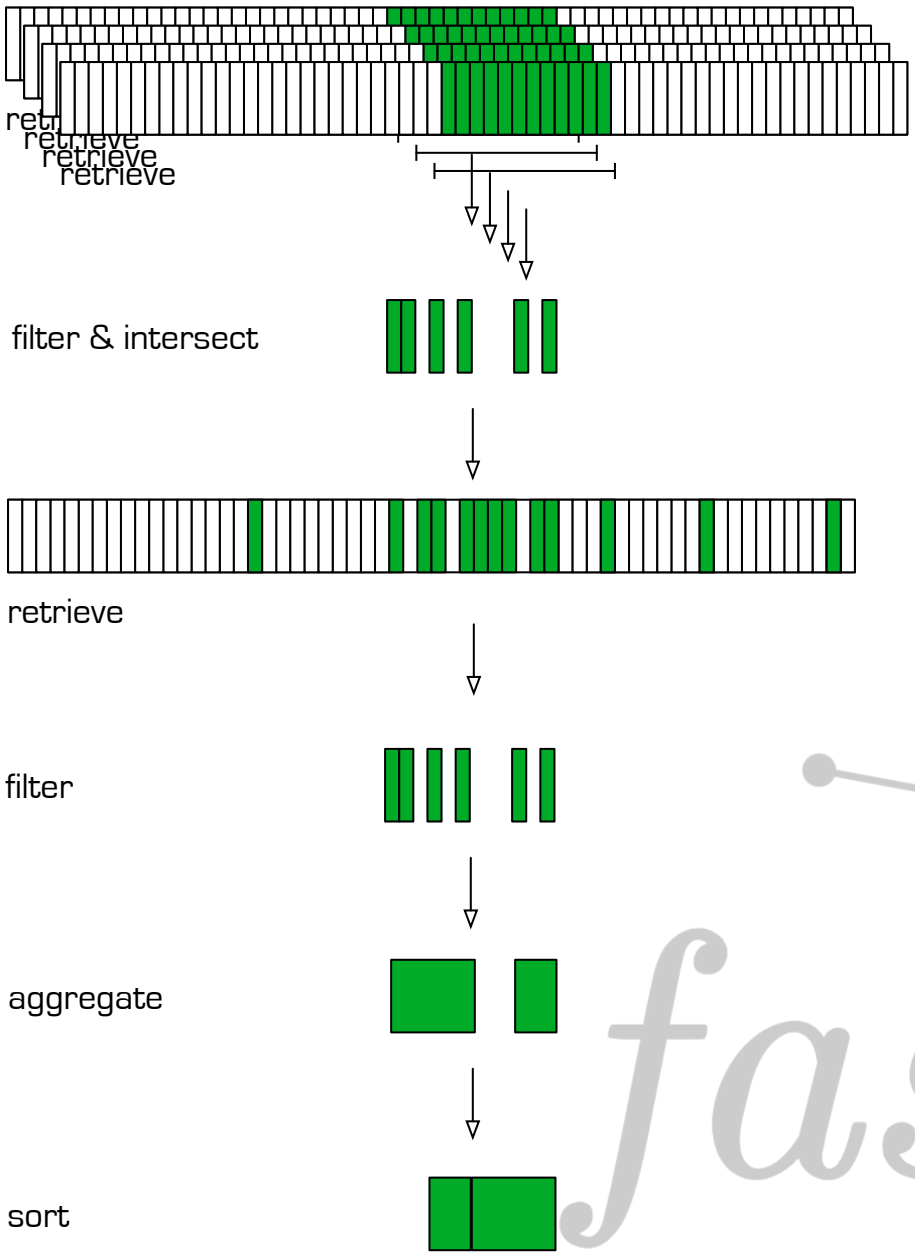
- All resources consumed, database corrupted, hate gizzards swollen.

- Architecture scales poorly to queries touching billions of records – **linear on number of records**.
- HBase in late 2009 extremely fragile, especially on low-end hardware.



Second Attempt

- Insert records into Cassandra.
- Random partitioner and indexing to evenly distribute load.
- Index every dimension independently.
- Multi-step retrieval & set operation process to determine all records of interest.
- Finally, aggregate and sort.

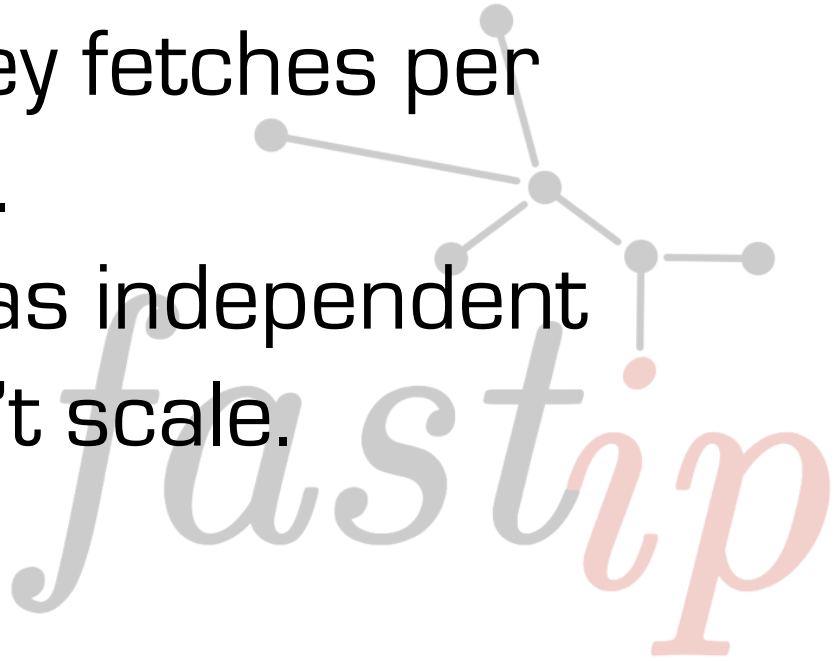

retrieve
retrieve
retrieve
filter & intersect
retrieve
filter
aggregate
sort

Apply Load

Second Failure

- Write load enormous, query latency agonizing, hate gizzards swollen.

- Repeated, multi-million key fetches per query makes things slow.
- Treating the application as independent of the database just won't scale.



Third Attempt

- Almost identical to previous...
- **BIG CHANGE**: Perform statistical sampling of records in the database.

Apply Load

Third Failure

- Write load enormous, query latency only marginally better, results unreliable, hate gizzards swollen.

- Sampling is unstable without sophisticated algorithms.
- Both too slow and surprising. In a bad way.

Pause. Regroup.

Our mental model is obviously broken.
What is a better one?

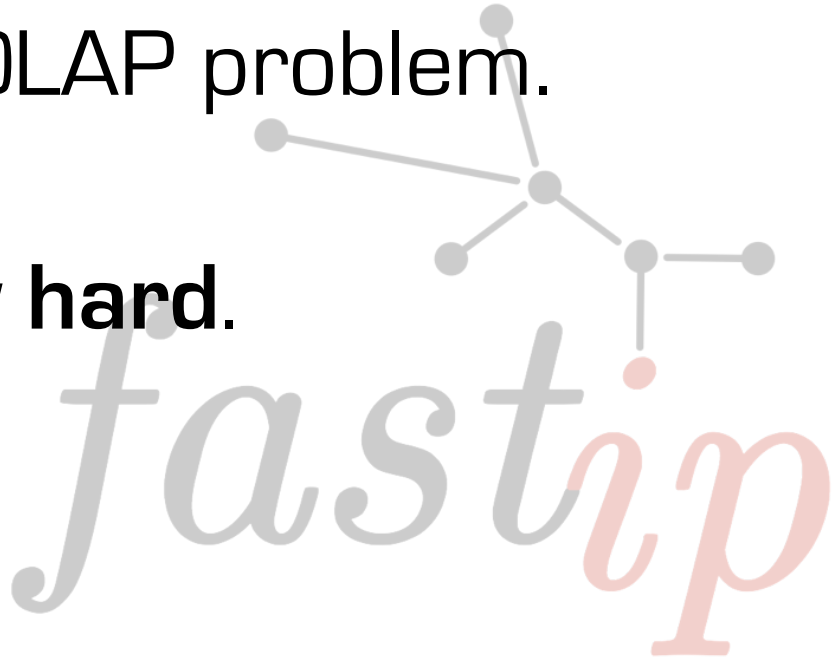
Hit the library: **Citeseer**.

Epiphany

We have an OLAP problem!

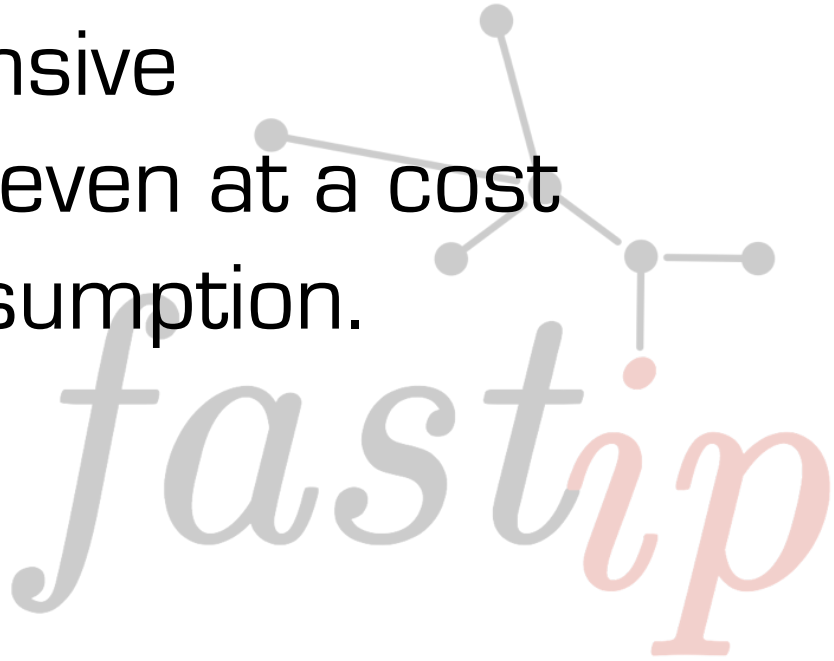
Not just **any** OLAP problem, but a real-time, high-dimensionality OLAP problem.

Not impossible, **just really hard**.



What is OLAP?

A business intelligence (BI) approach to "swiftly answer multi-dimensional analytics queries" by structuring the data specifically eliminate expensive processing at query time, even at a cost of enormous storage consumption.



The Cube

OLAP systems rely on pre-computing results, then filtering, sorting, and aggregating to produce results. The artifact of the pre-computation is a hypercube with size proportional to the dimensionality and cardinality of the data.

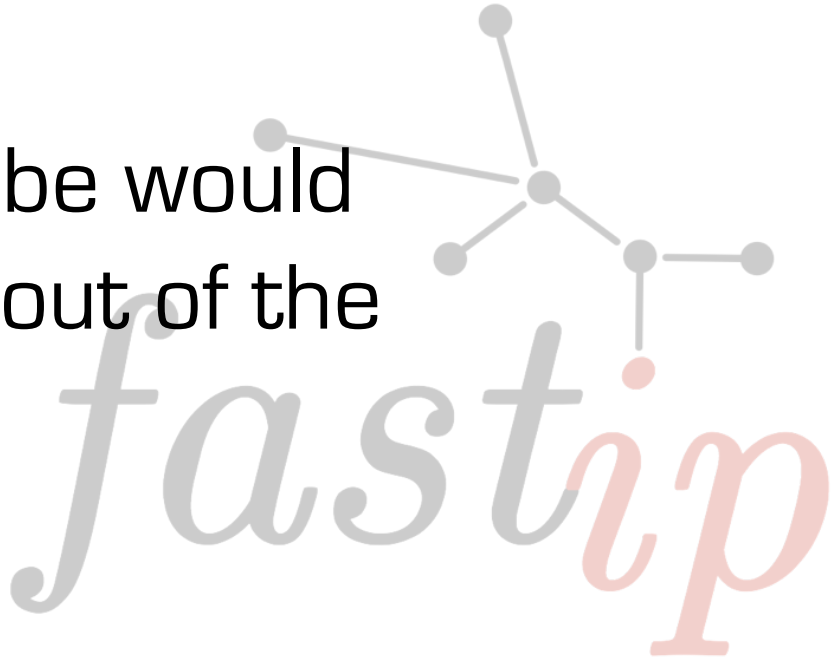
Dimensionality

We have dozens of dimensions;
Materializing the entire cube would require absurd memory – out of the question.

Cardinality

The number of unique values possible for each dimension. We have a lot of these, too – thousands to billions.

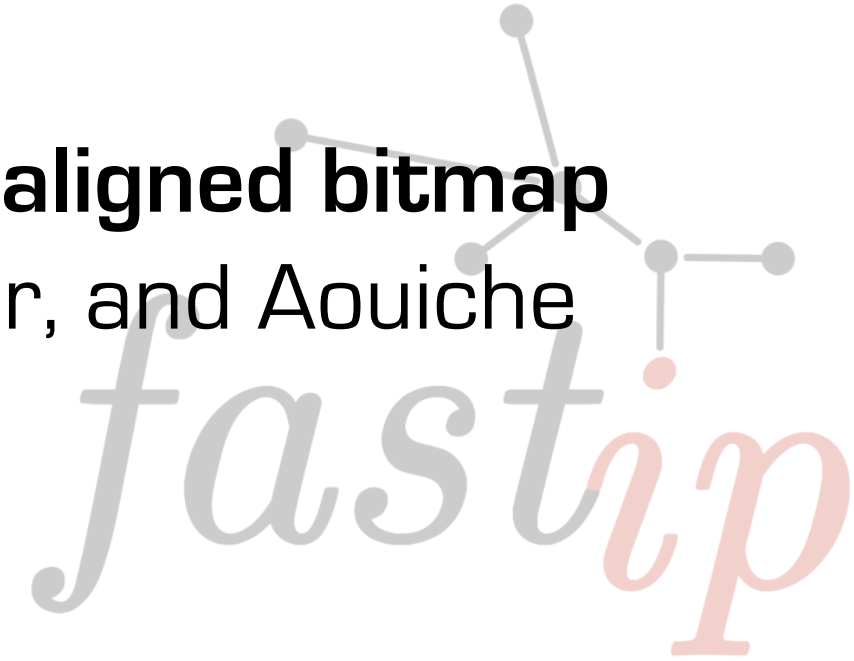
Materializing the entire cube would require absurd memory – out of the question.



Strategery

Starting points:

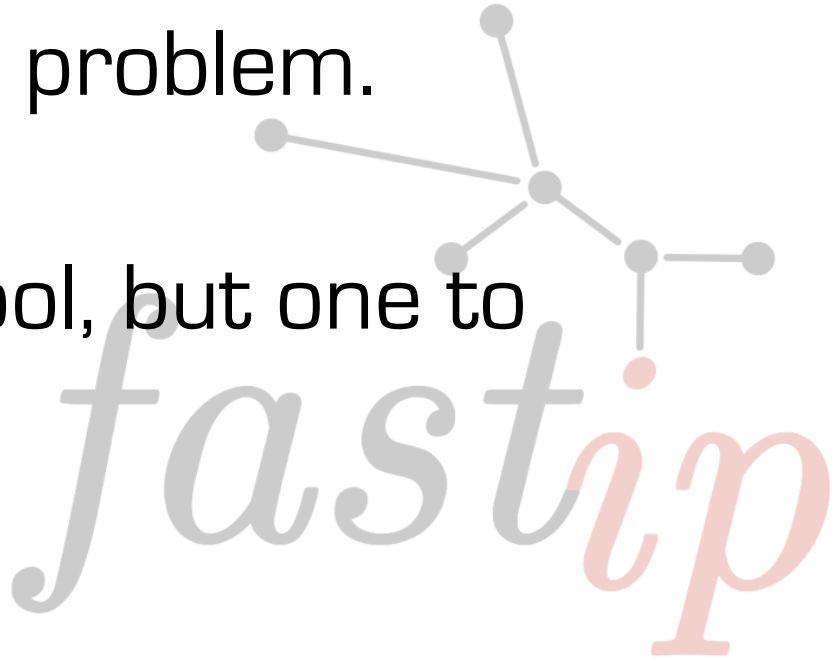
- **High-Dimensional OLAP: A Minimal Cubing Approach** by Li, Han, and Gonzalez
- **Sorting improves word-aligned bitmap indexes** by Lemire, Kaser, and Aouiche



Research

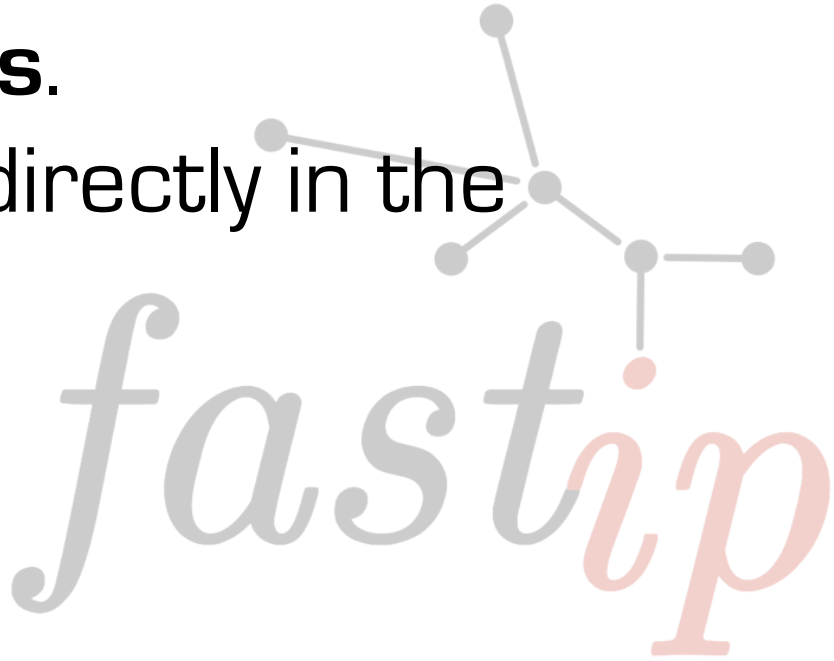
Academic research can point you in a direction, but it is rarely a complete solution. Even more rarely is it a complete solution for your problem.

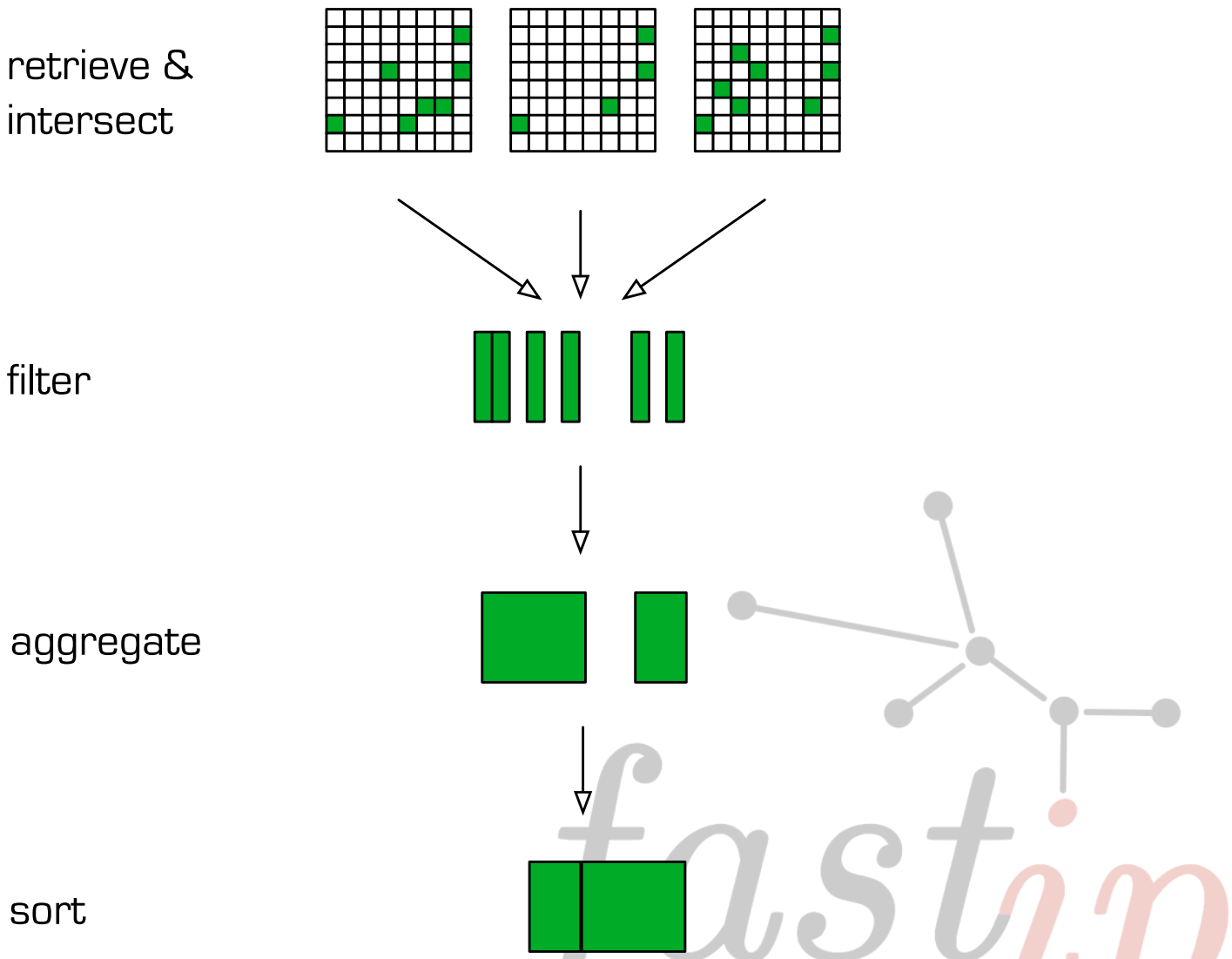
A useful, even essential, tool, but one to be used with great care.



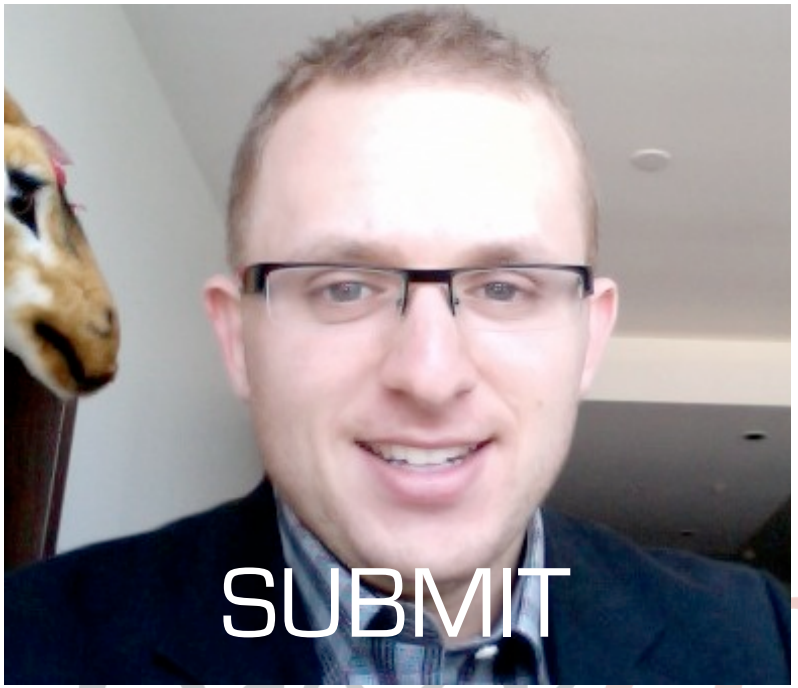
Fourth Attempt

- Insert records into Cassandra.
- Materialize lower-dimensional cuboids using bitsets, join as needed. **This is a lot harder than it sounds**.
- Perform all query steps directly in the database. **So is this**.



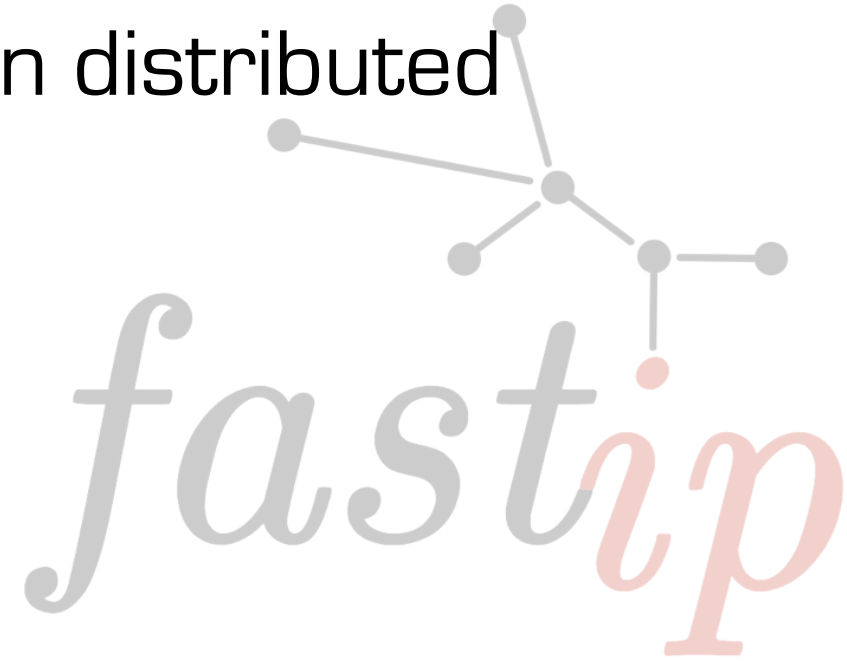

retrieve &
intersect
filter
aggregate
sort

Apply Load



Success!

- Low write load.
- Low latency – compact indices mean more of them in memory.
- Distributed cuboids mean distributed load.
- Hate gizzards shrink.

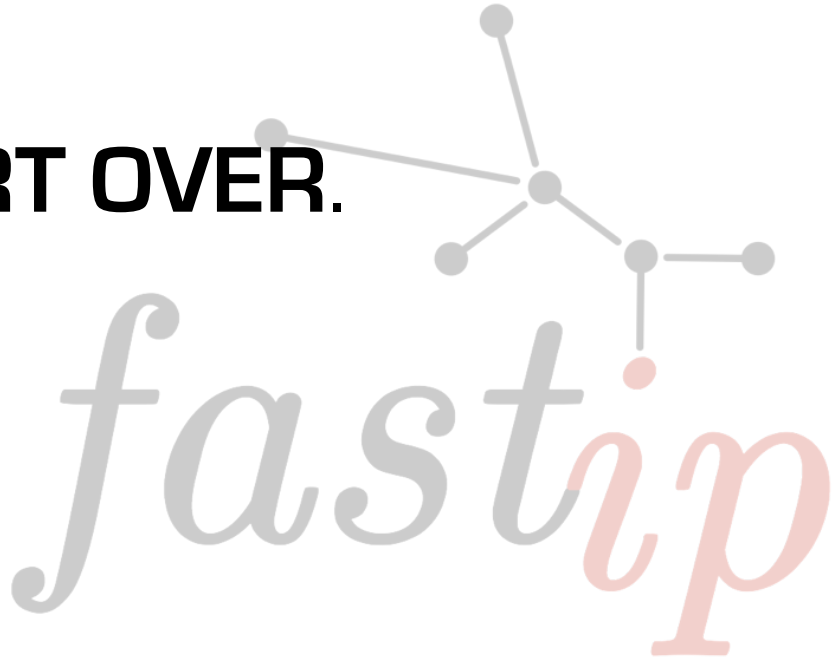


More To Do

- Data-specific indices – network prefix queries, etc.
- On-disk structures specific to our application.
- **MORE MAGIC.**

Lessons

- **READ THE LITERATURE!**
- Generic software is 90% wrong at scale, you just don't know which 90%. **ITERATE TO DISCOVER**.
- **BE PREPARED TO START OVER**. Repeatedly.
- **DON'T GIVE UP!**



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