RASED: A Scalable Dashboard for Monitoring Road Network Updates in OSM

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University of Minnesota

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UNIVERSITY OF MINNESOTA
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Outline

1. **Motivation**
2. **RASED Queries**
3. **RASED Architecture & Main Modules**
   - Data Collection & Processing
   - Storage & Indexing
   - Query Execution
   - User Interface
4. **Experimental Results**
5. **RASED in Action (A Quick Demo)**

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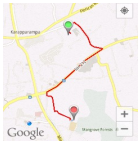
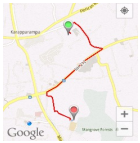


Range Query Routing …

Road Network Queries…



Range Query

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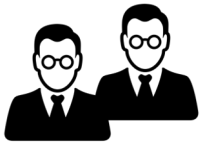
…

Map Analyzers



Quality Assessment

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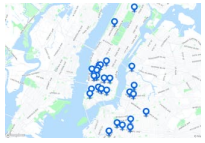

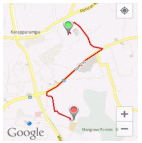

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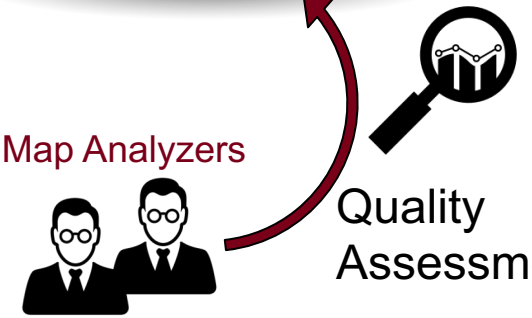

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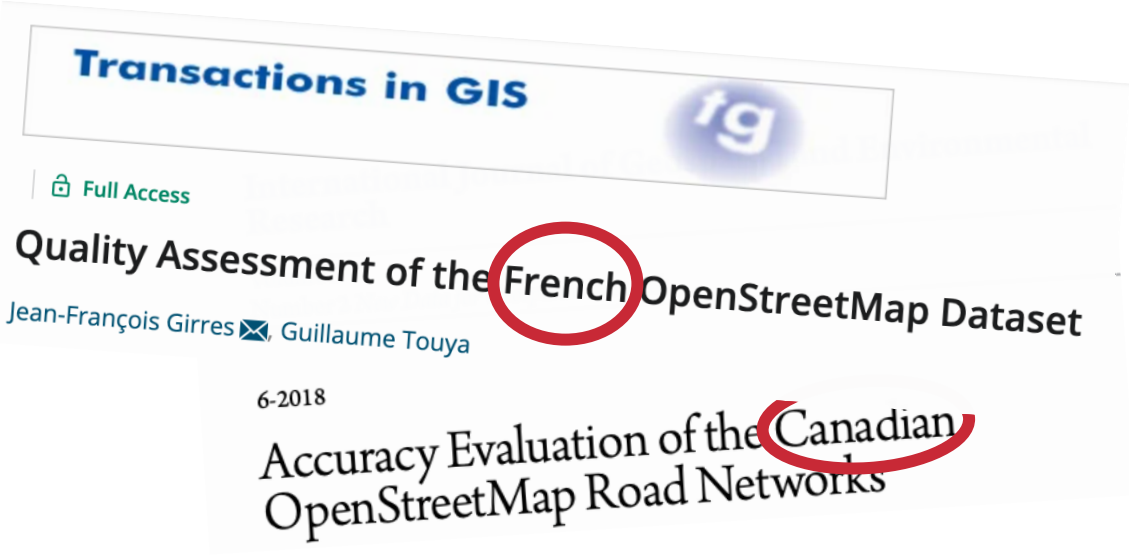

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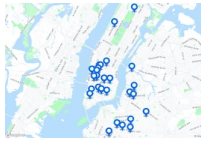

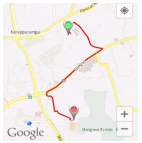

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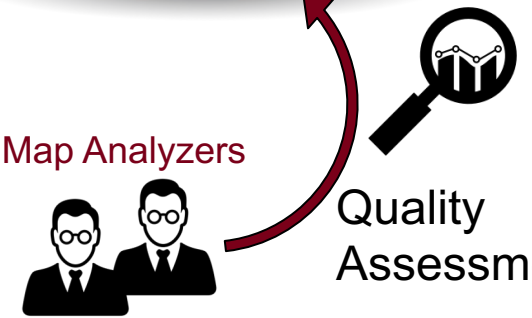
OSM:

- **12+ Billion updates**
- **3 TB Data**



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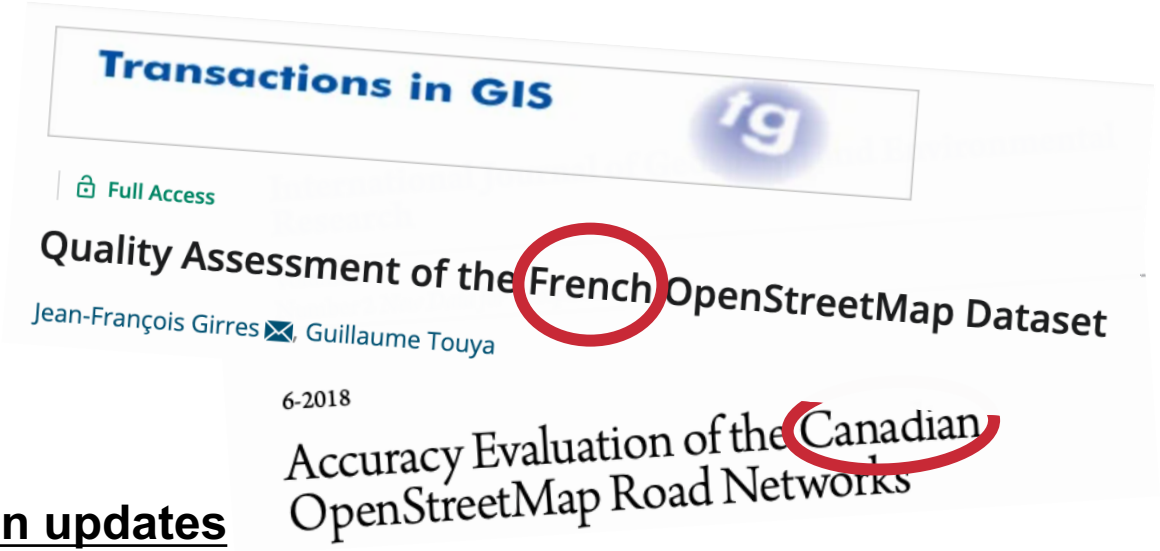

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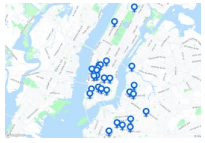

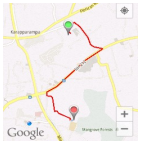

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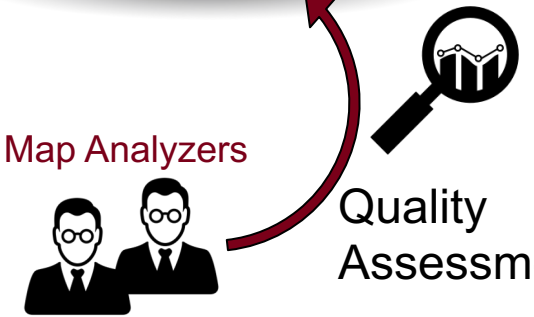

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Not Scalable

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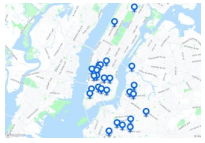

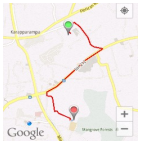

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RASED

- Global-Scale
- Comprehensive
- Highly Interactive

How does RASED Help Map Analyzers?

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- Road changes - > gives road network stability
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- 15 years worth of data
- Scalable, Interactive dashboard

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RASED is the first-ever attempt to **quantify** and **visualize all** OSM **worldwide** changes on a **daily** basis

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RASED Analysis Queries

Example UpdateList U

Date	Country	RoadType	ElementType	UpdateType	Latitude	Longitude	ChangesetID
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- **Filters**: Temporal (e.g., time of update), spatial (e.g., country or state), road types, and update types.
- **Goal:** find number and percentage of OSM updates:
  - E.g., per country, comparison between countries, types of updated roads, and temporal evolution of updates.

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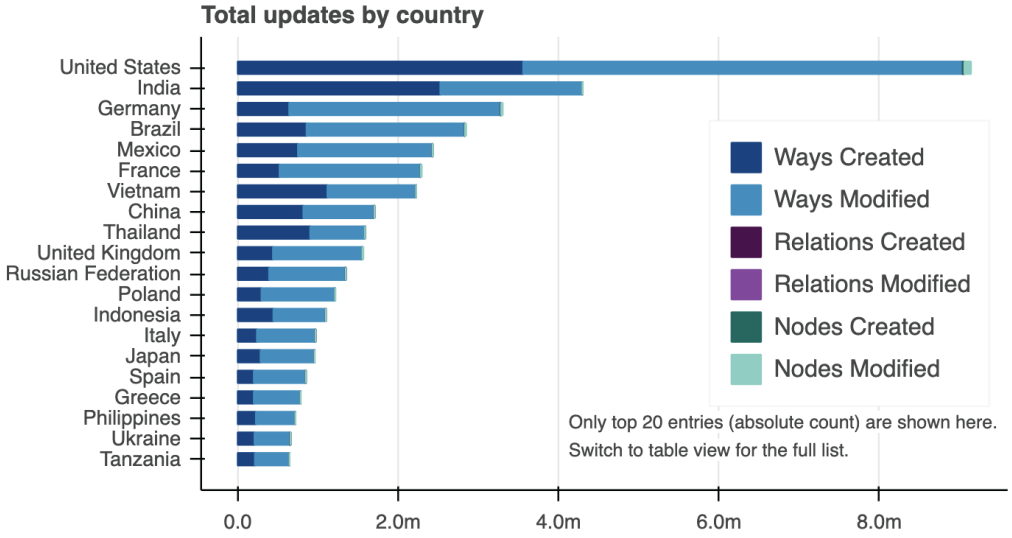

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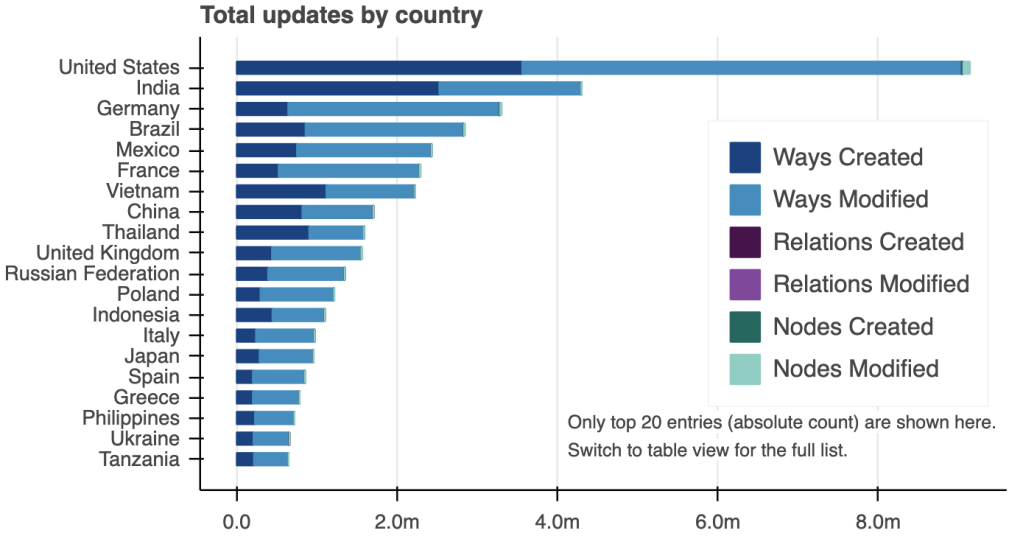
  AND U.UpdateType IN [New,Update]
GROUP BY U.Country, U.ElementType
```



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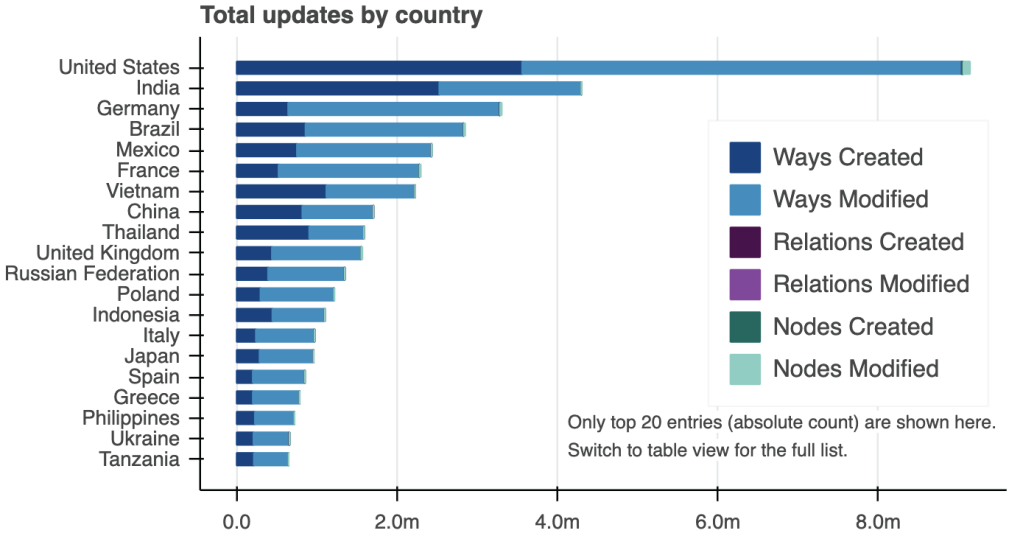

RASED queries are always supported in the order of **milliseconds** regardless of how large is query period.

RASED Analysis Queries

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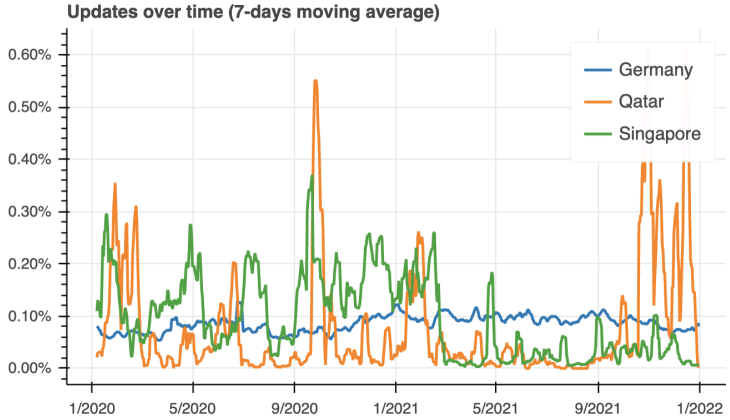
Compare the percentage of daily changes in road network in Germany, Singapore, and Qatar over 2020 and 2021.



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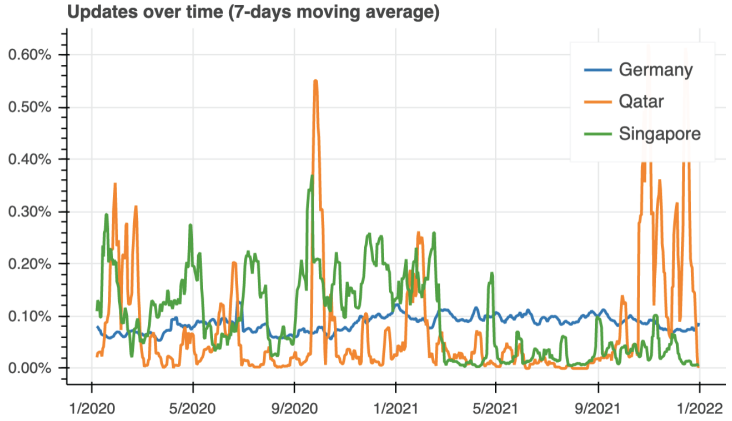
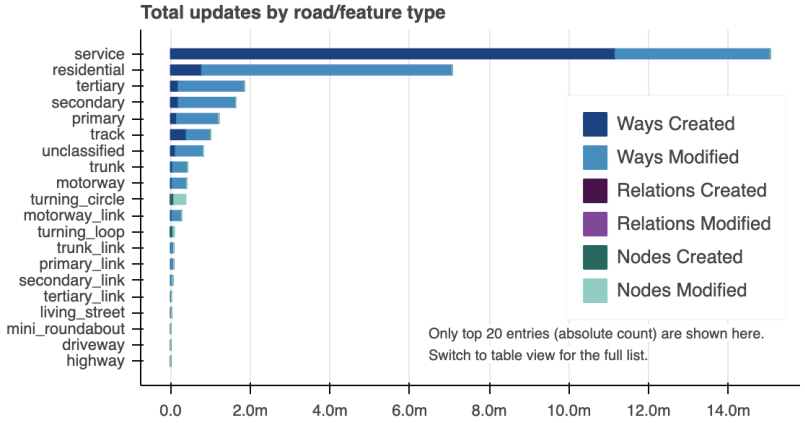


Example 3:

Find the number of newly created or modified elements types (node, way, relation) for each road type in USA since 2018.



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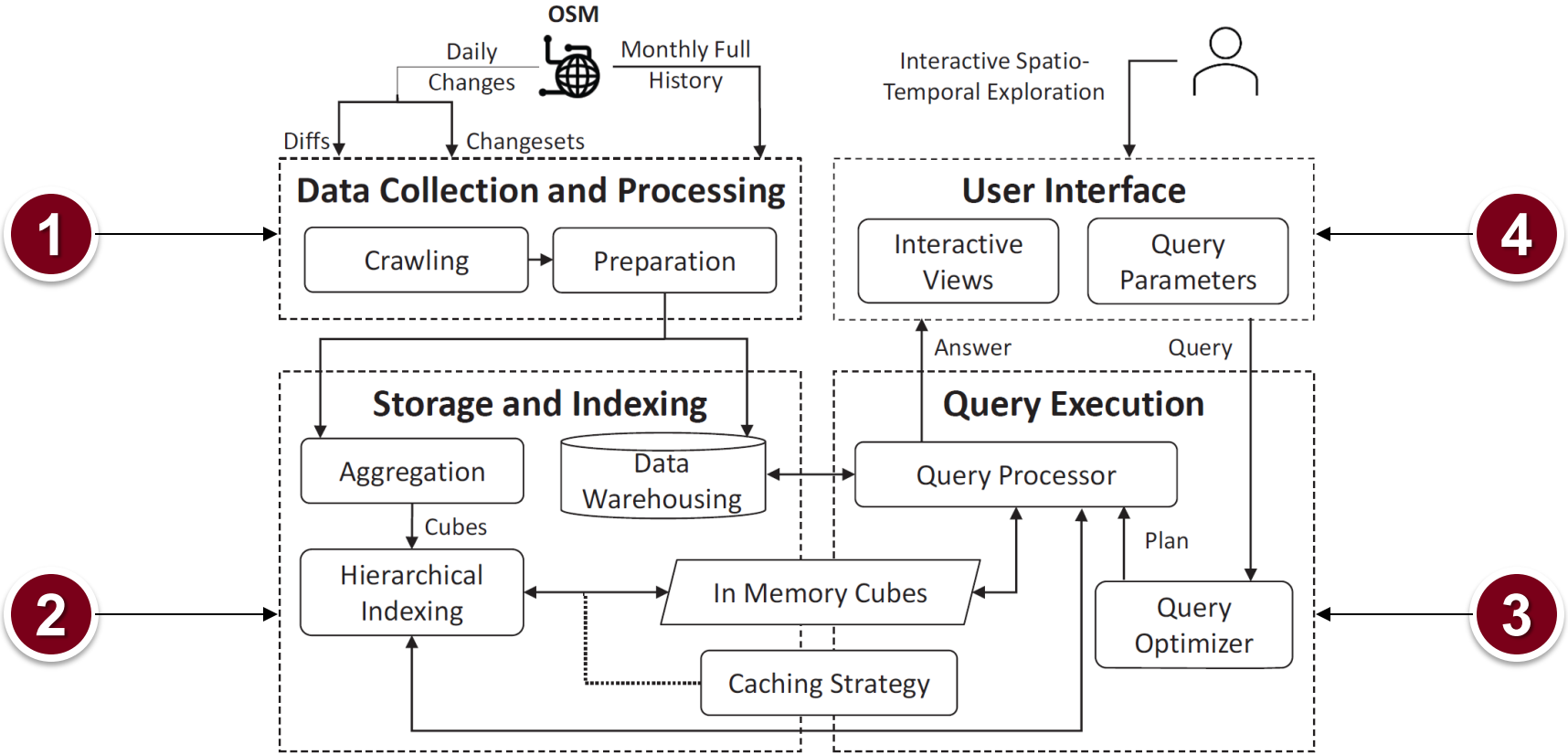

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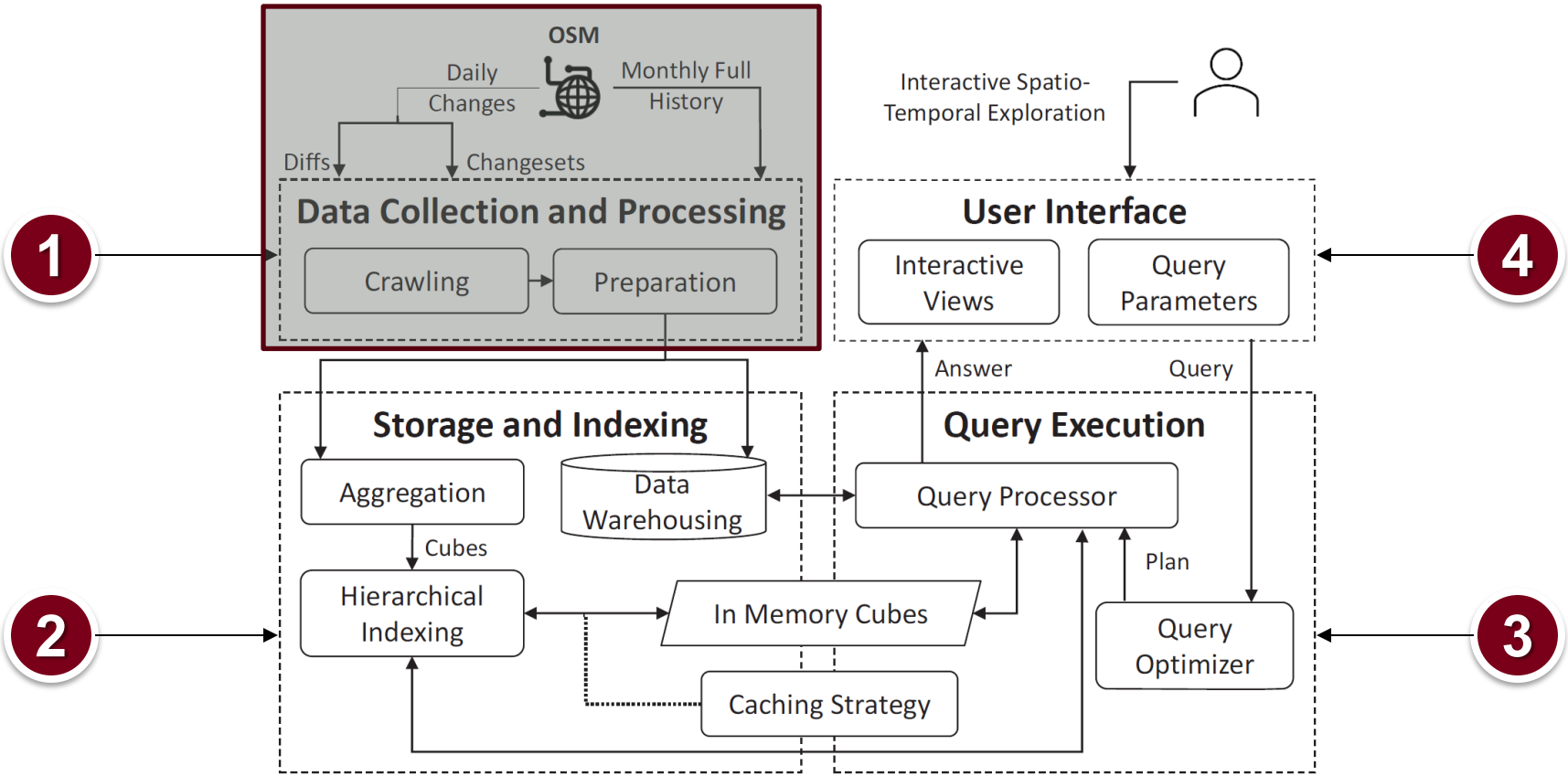

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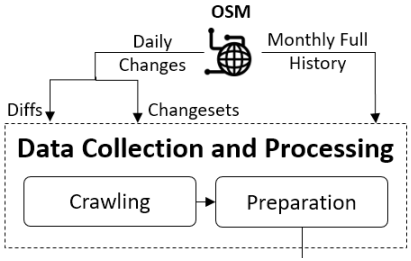

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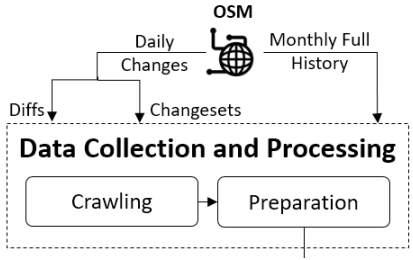
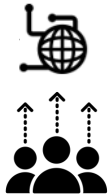


Planet.osm



300K
active users

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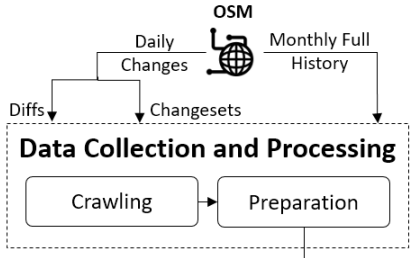

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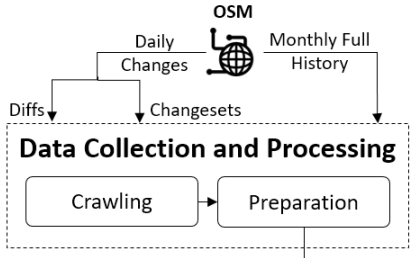

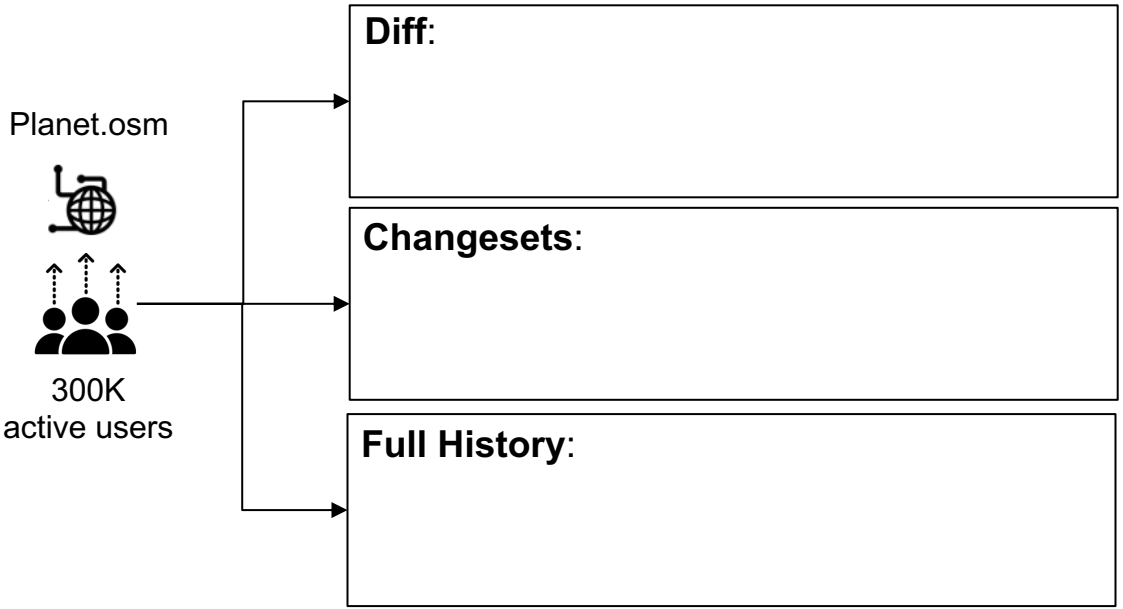

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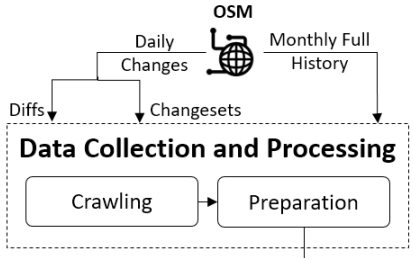

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Diff: only new versions of updated roads

	Minute	Hour	Day
# Files	5M	82K	3.5K

Few GB each

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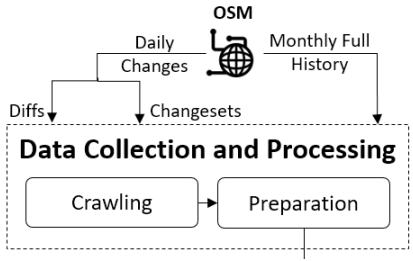

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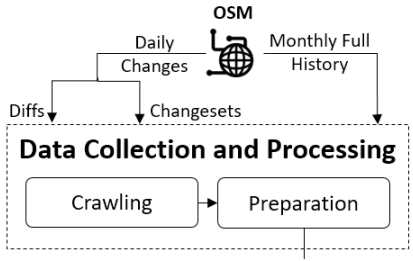

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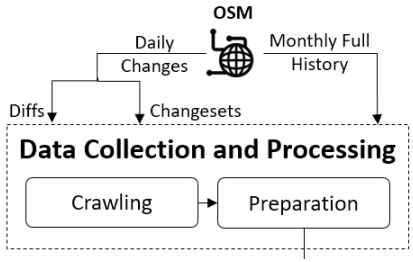

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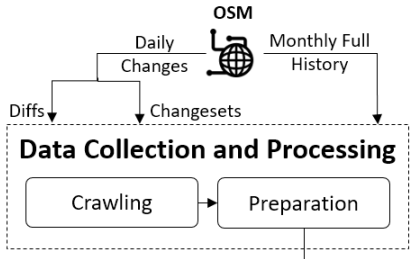

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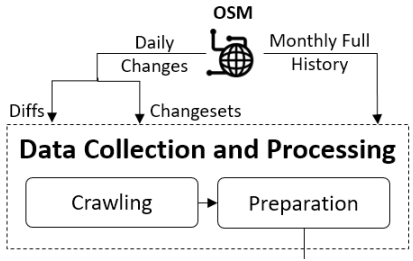

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Up to date statistics

Daily Crawler

More Details
Complete Missing information

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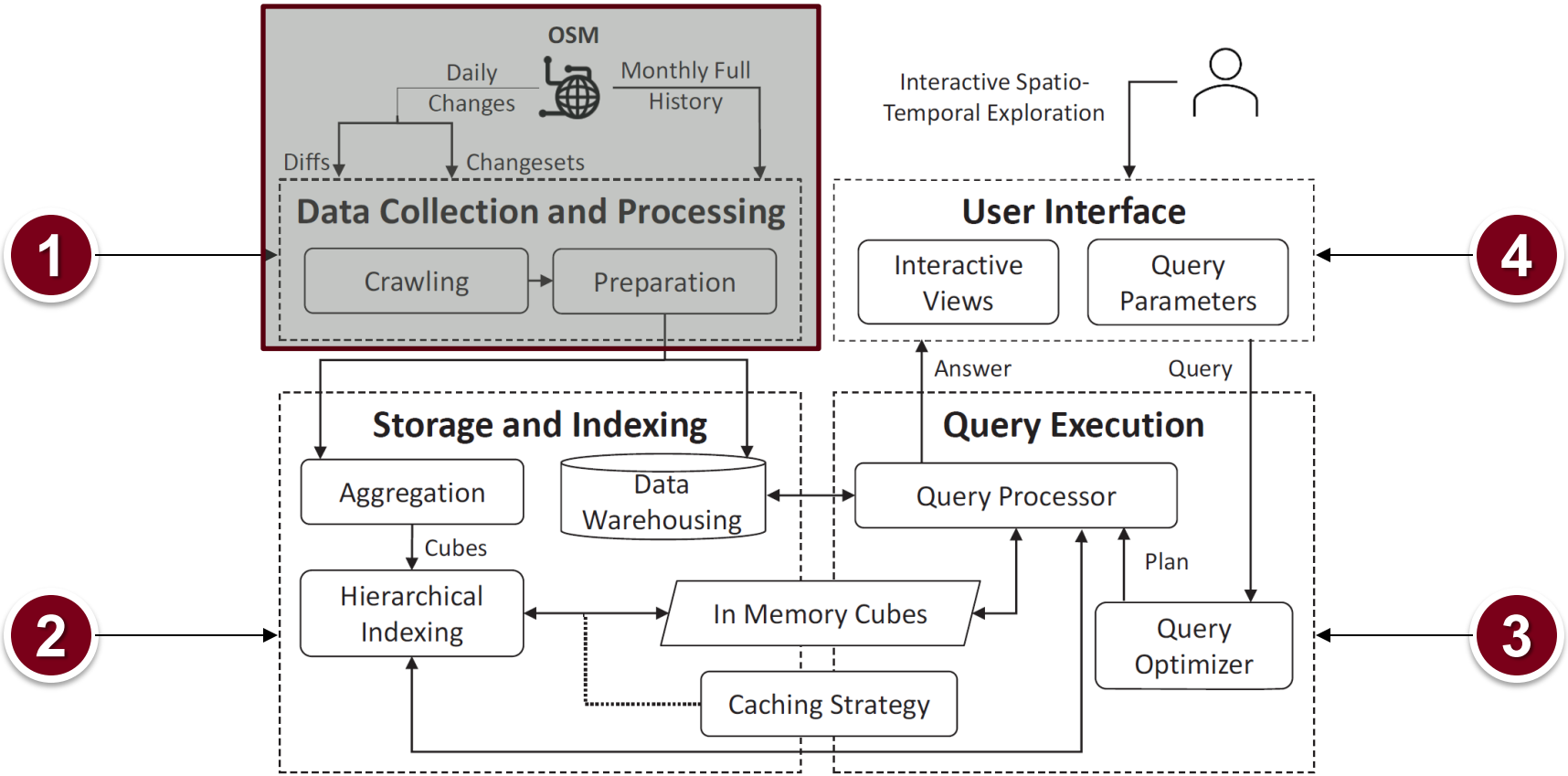

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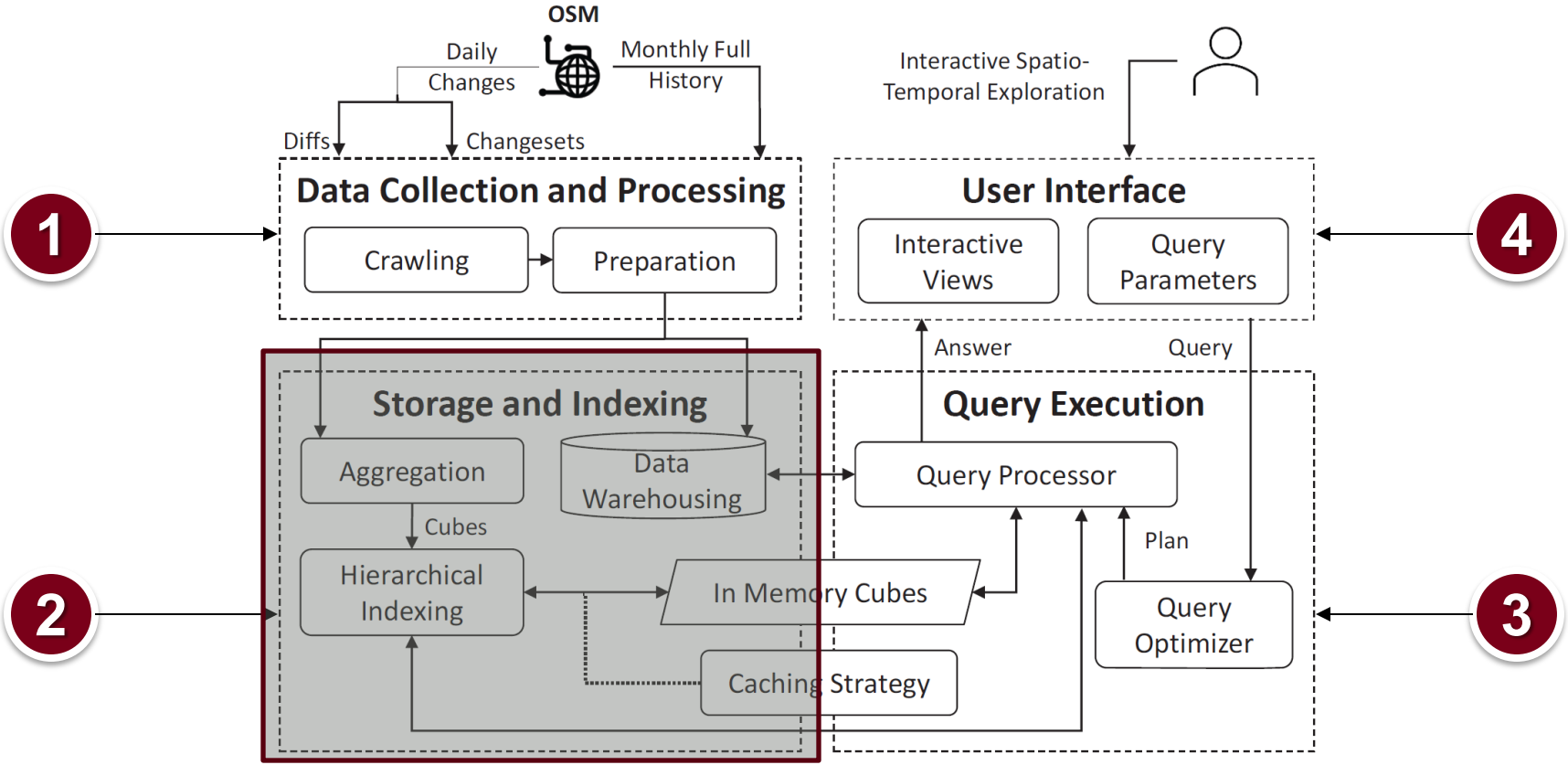

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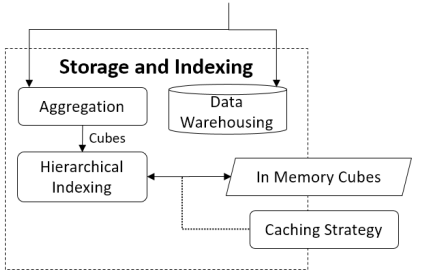

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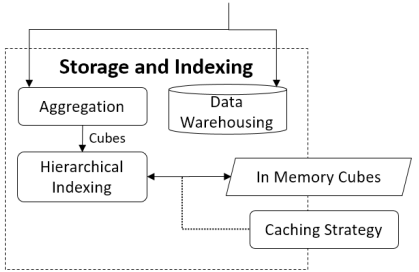
Daily Update List → **This Module**



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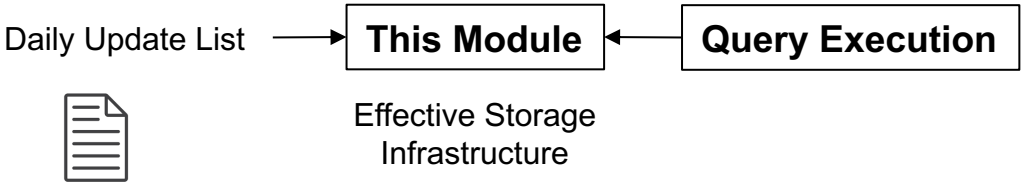
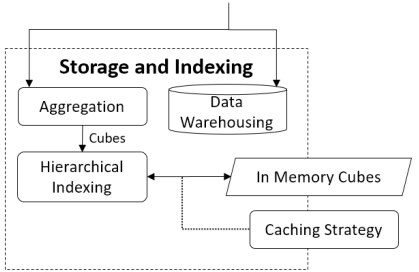




2- Storage and Indexing

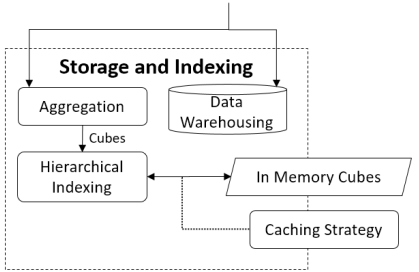
Daily Update List → **This Module** ← **Query Execution**

Effective Storage Infrastructure

Very few I/O

RASED Analytical Queries:

- Global-Scale
- Comprehensive
- Highly Interactive



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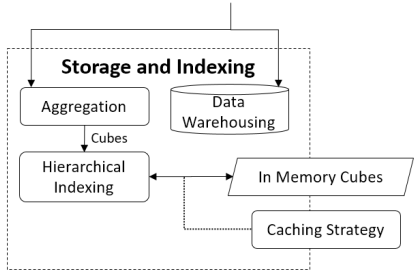

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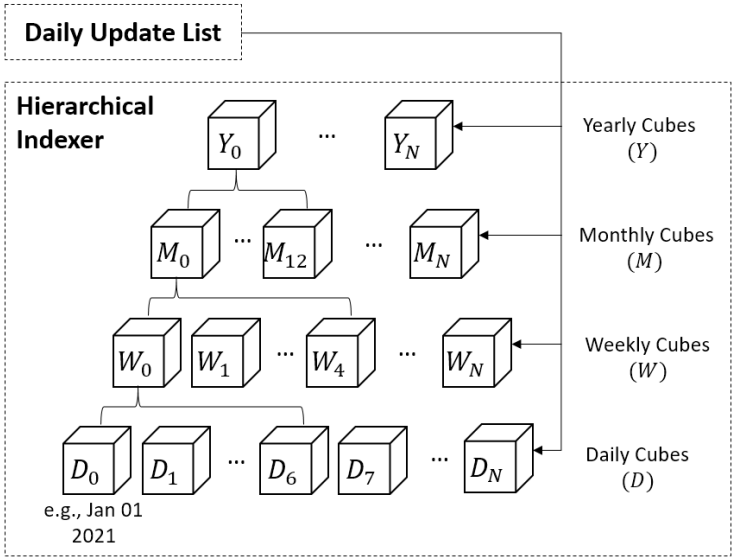
Hierarchal Temporal Index



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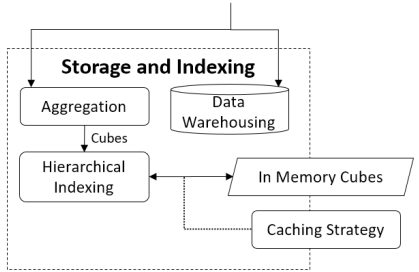

Daily Update List → **This Module** ← **Query Execution**

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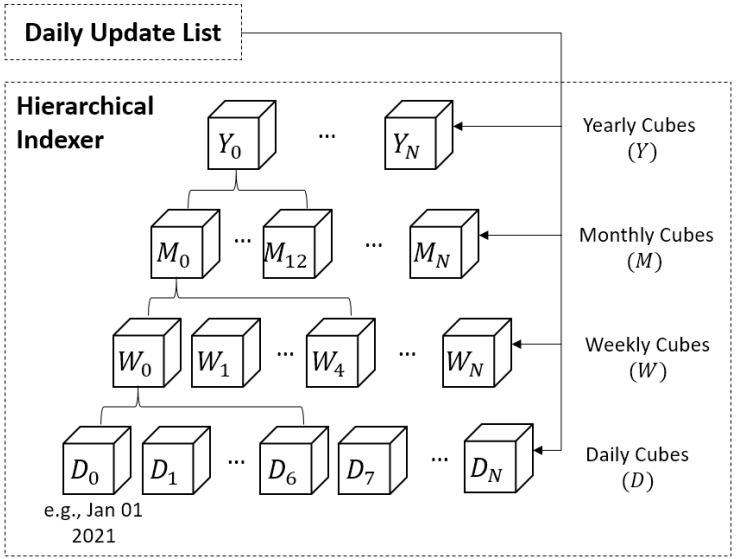
Index Nodes

- Precomputed statistics, not map updates itself
- Stored as 4-dimential data cubes:
  - ***Country***: 300+ values
  - **Road Type**: 150 values
  - **Update Type**: 4 values
  - **Element Type**: 3 values.

Hierarchal Temporal Index



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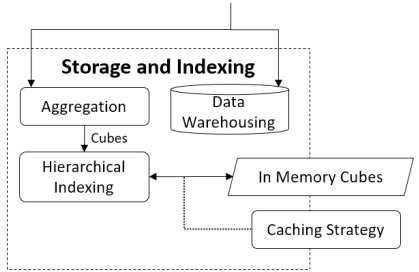

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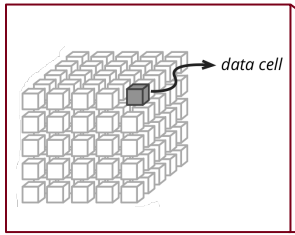
- Stored as 4-dimential data cubes:
  - ***Country***: 300+ values
  - **Road Type**: 150 values
  - **Update Type**: 4 values
  - **Element Type**: 3 values.
- Each cube:
  - has 540,000 precomputed values (cells)
  - covers a specific period (e.g., week)
  - ~4MB, one disk page.
- Each cube cell is the aggregate count of OSM updates



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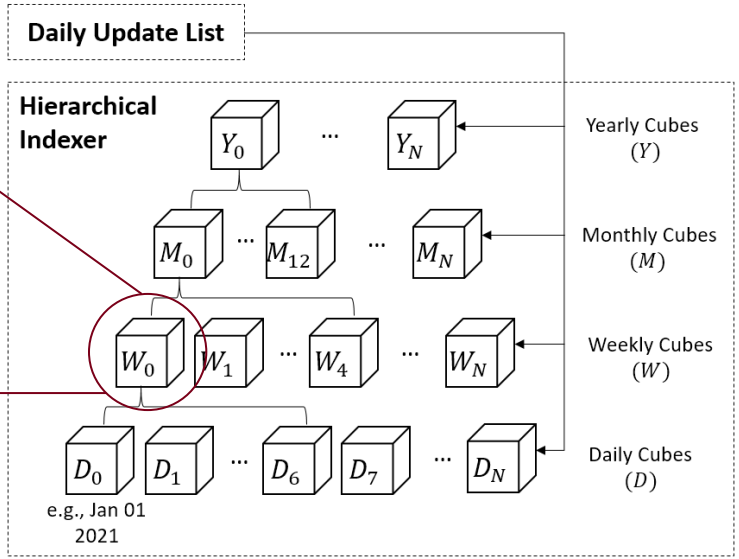
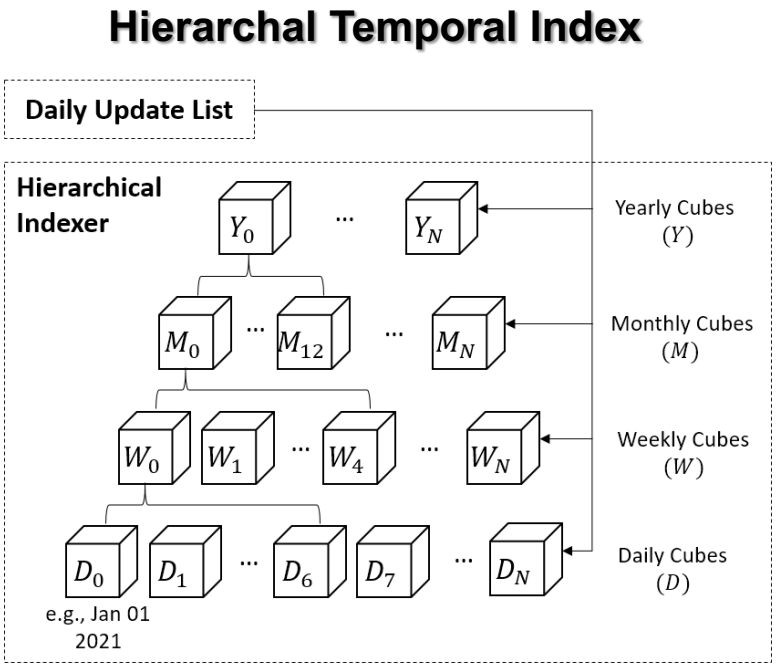


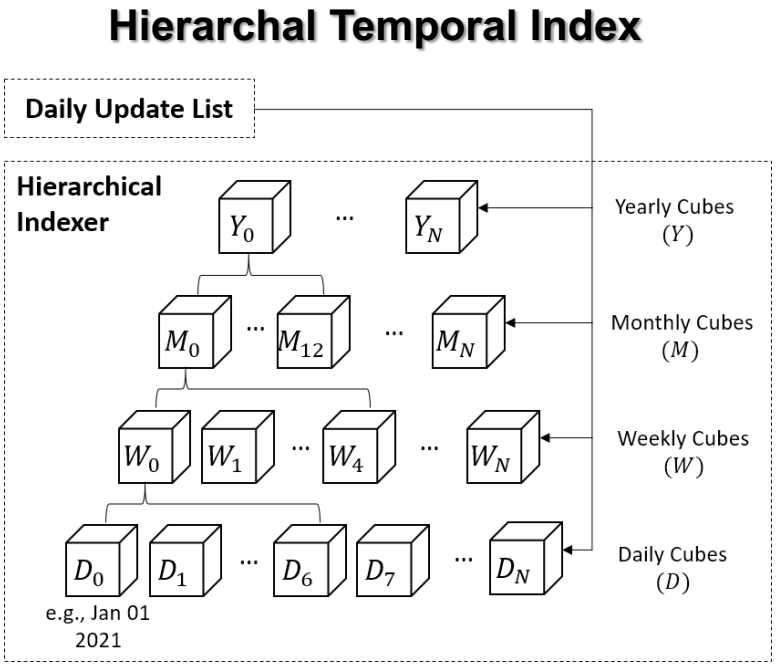
RASED Hierarchical Temporal Indexing



RASED Hierarchical Temporal Indexing

Index Hierarchy

Four levels:
- yearly
- monthly
- weekly
- daily



RASED Hierarchical Temporal Indexing

Index Hierarchy

Four levels:
- yearly
- monthly
- weekly
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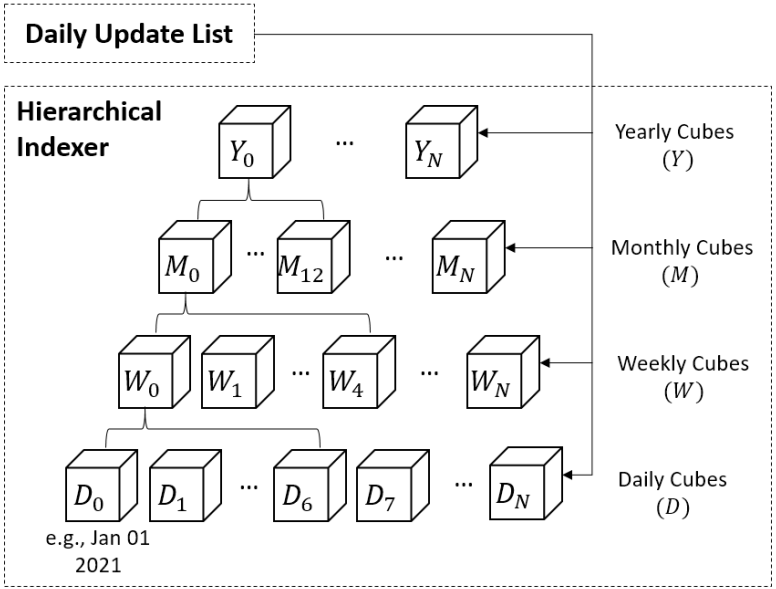
Index Size

OSM updates since 2004:

6,000+ daily nodes
200+ monthly nodes
850+ weekly nodes
16 yearly nodes

7,000 nodes / **4 billion** aggregate values / **~28GB**

Hierarchal Temporal Index



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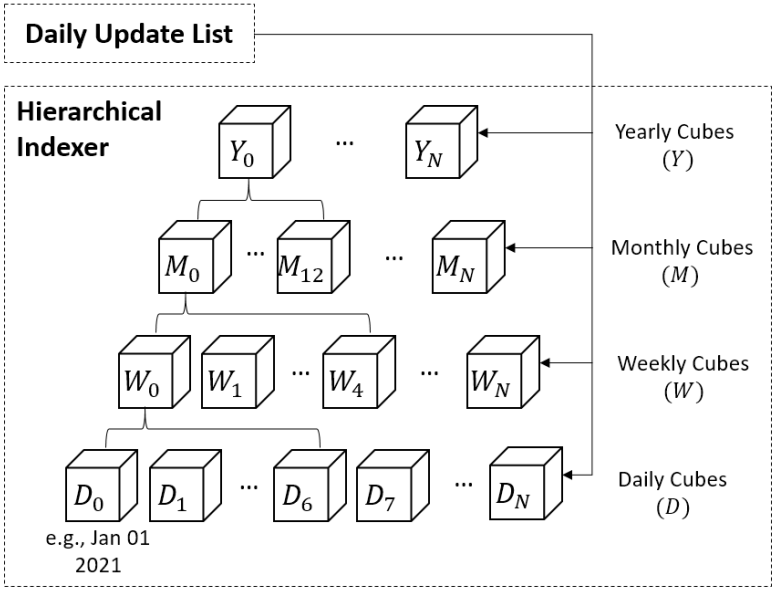
Index Maintenance

Daily updates :
- every day constructs & appends new daily cube
- Recursively build weekly/monthly/yearly cubes
- offline, ~30 minutes

Hierarchal Temporal Index



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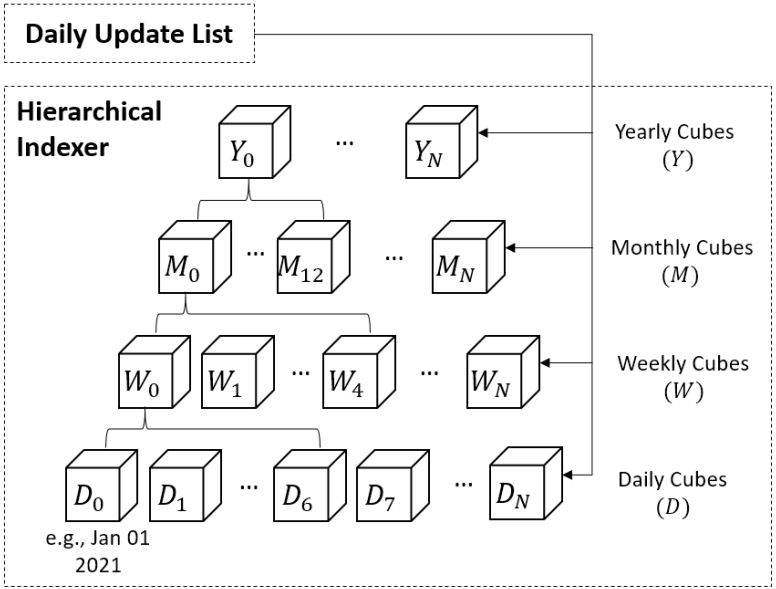
Index Maintenance

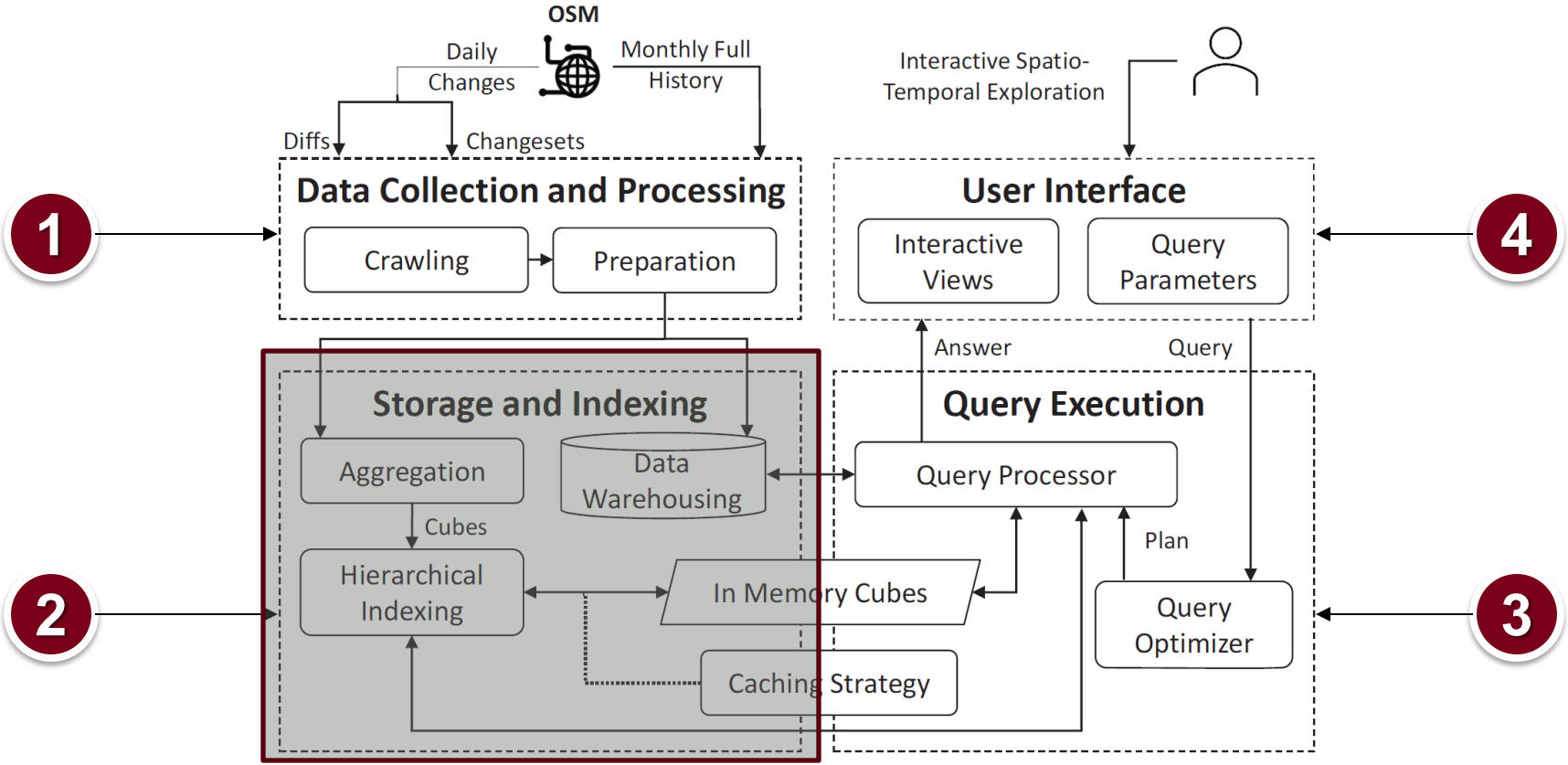
Daily updates :
- every day constructs & appends new daily cube
- Recursively build weekly/monthly/yearly cubes
- offline, ~30 minutes

Monthly updates: more information obtained:
- reconstruct daily & weekly cubes
- offline, ~few hours.

Hierarchal Temporal Index



RASED Architecture



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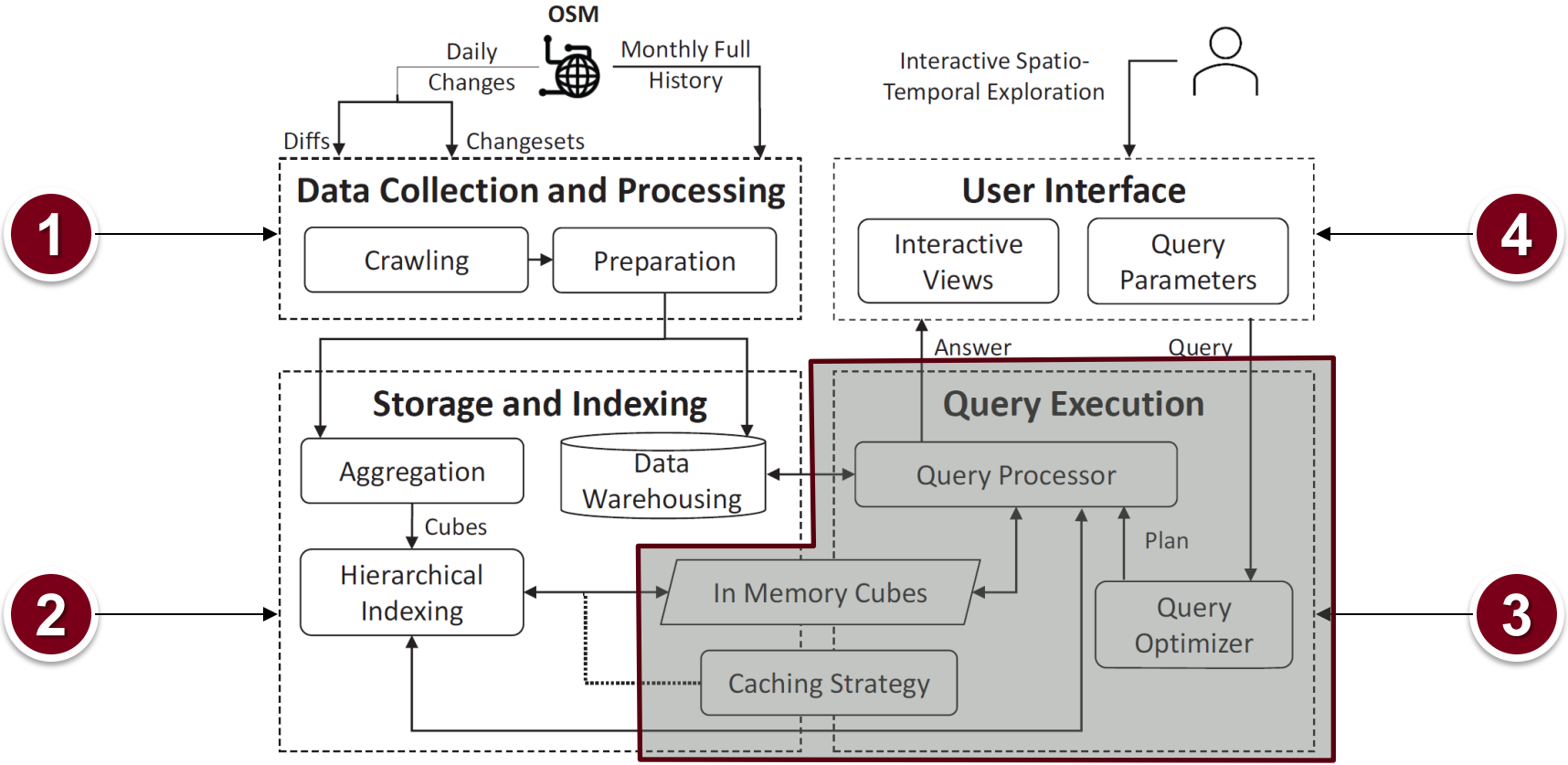
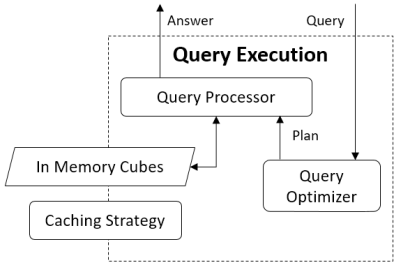
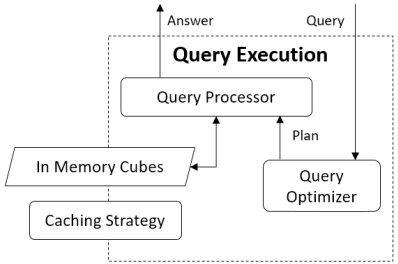


3- Query Execution



3- Query Execution

Ex. Find number of updates in each country in time window t.



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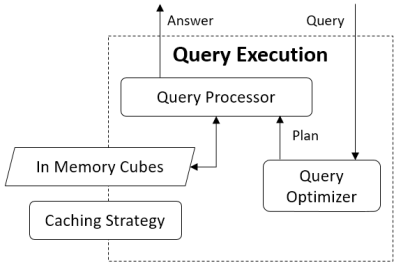
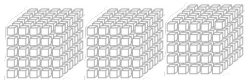


Ex. Find number of updates in each country in time window t.

Two phases:

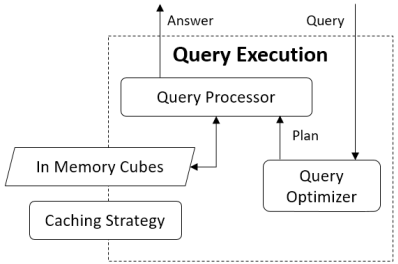
Retrieves cubes satisfies t



All dimensions

1

3- Query Execution



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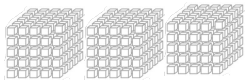
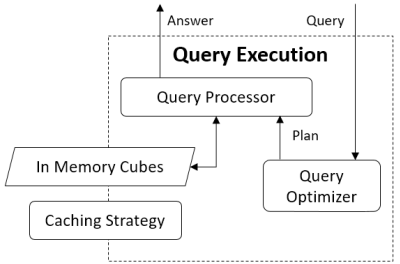


All dimensions

1

Disk-Based

3- Query Execution



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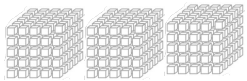


All dimensions

1

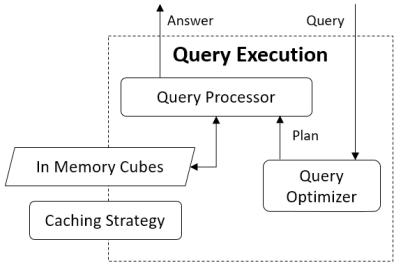
Disk-Based

Aggregates unwanted dimensions
Keep only requested ones

Country

2

3- Query Execution



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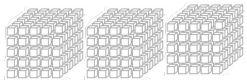

All dimensions

1

Disk-Based

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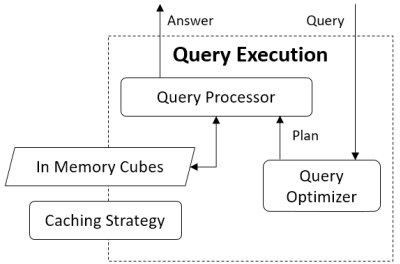
Country

2

In-Memory

3- Query Execution



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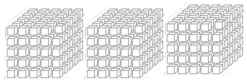

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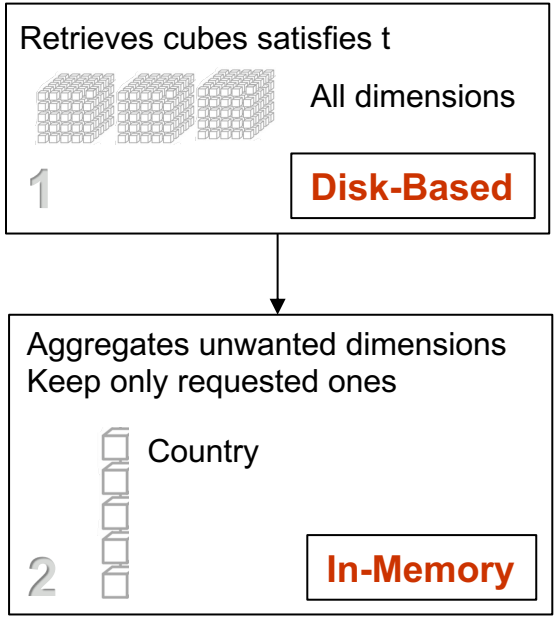
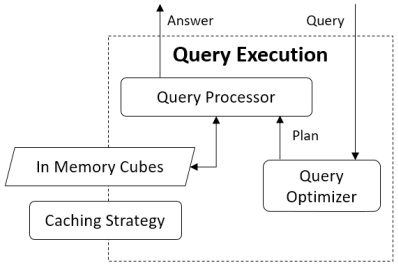


Two Disk Access optimization techniques

Caching & Level Optimization



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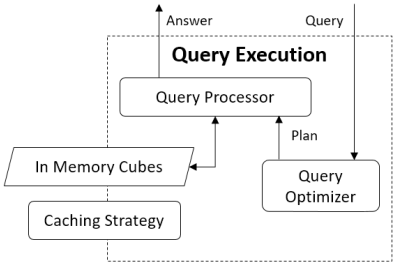

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Two Disk Access optimization techniques

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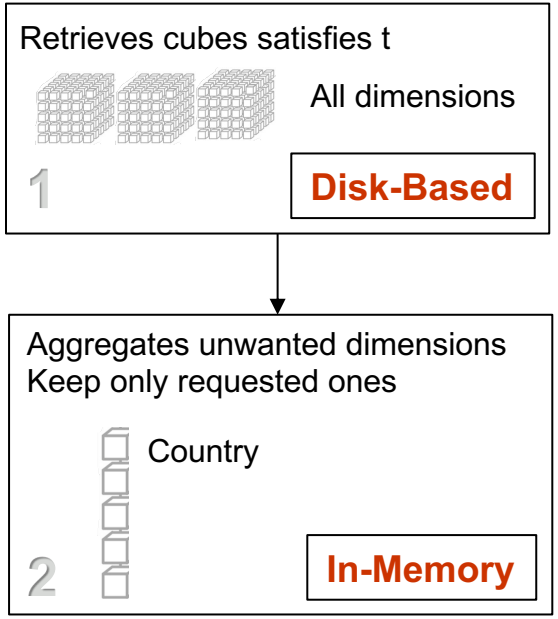
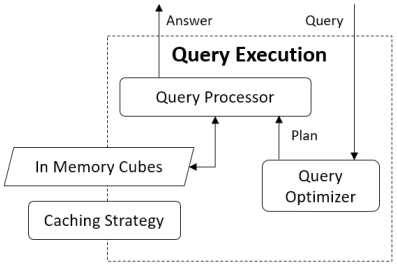


A. Caching

Goal:

- Preload recent data cubes into memory
- Reduce cubes retrieved from disk
- Reduce query response time

3- Query Execution



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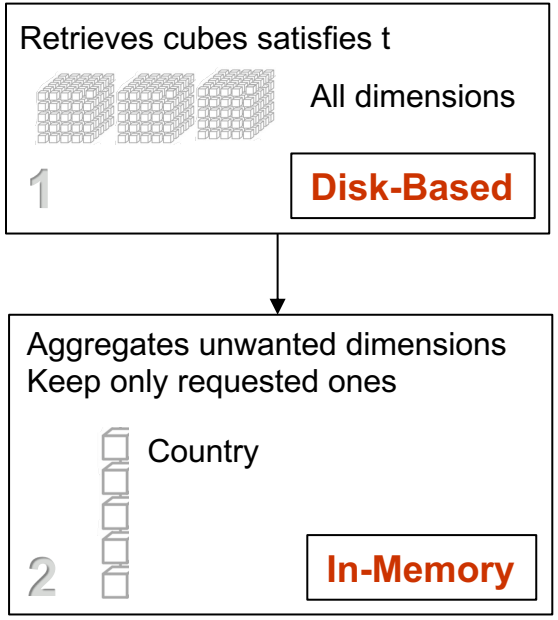

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Rational:
More likely to receive queries for recent updates

Challenge:
which level to preloaded data cubes from?

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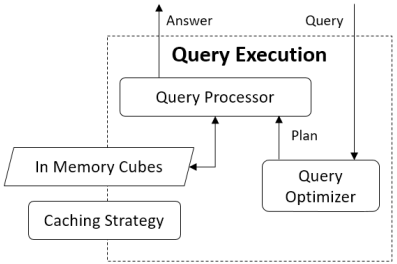

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Two Disk Access optimization techniques

Caching & Level Optimization

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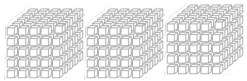

All dimensions

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2

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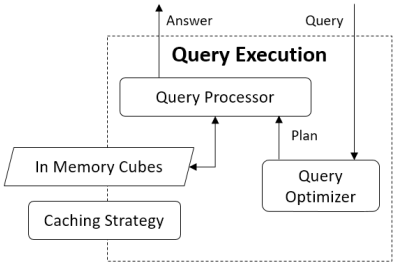
3- Query Execution



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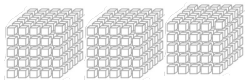

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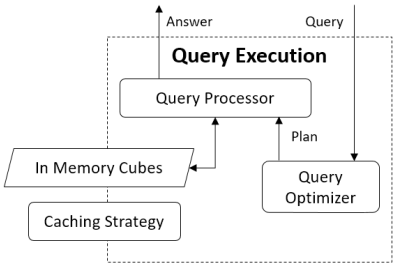
- N available memory
- α, β, γ, and θ: ratio allocated to each level
- trade off: *aggregation granularity* vs *time coverage*

3- Query Execution



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Two Disk Access optimization techniques

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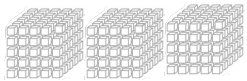

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Days Weeks Months Years

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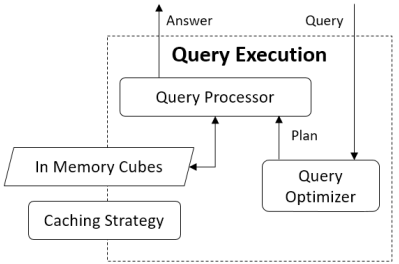
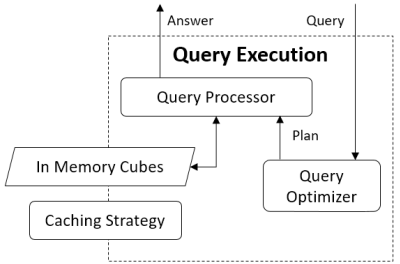
3- Query Execution



Two Disk Access optimization techniques

Caching & Level Optimization

3- Query Execution

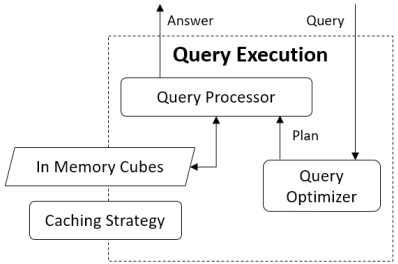


Two Disk Access optimization techniques

Caching & Level Optimization

B. Level Optimization

3- Query Execution



Two Disk Access optimization techniques

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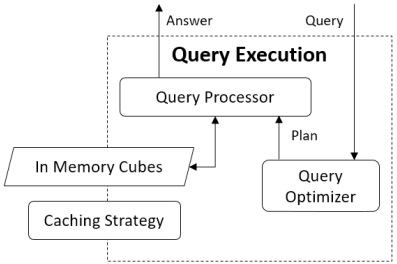

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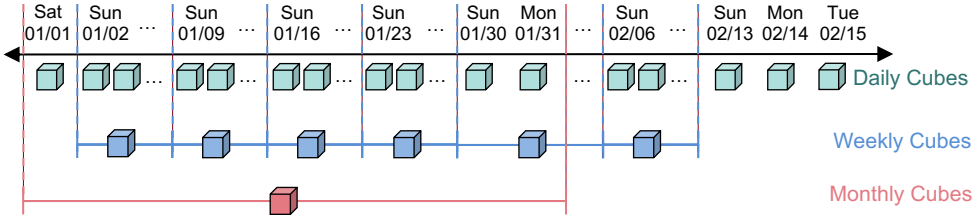

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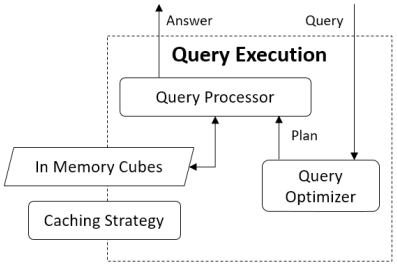

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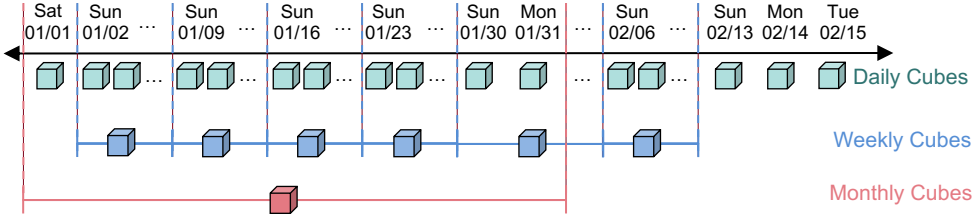

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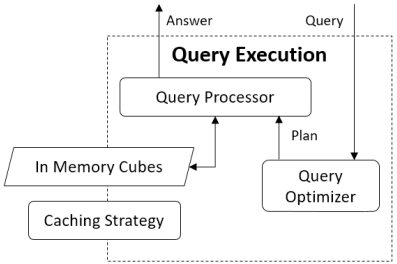

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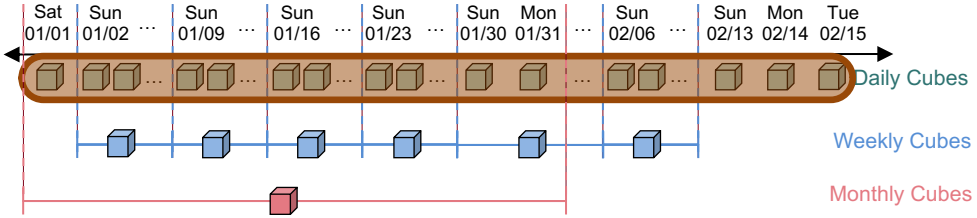

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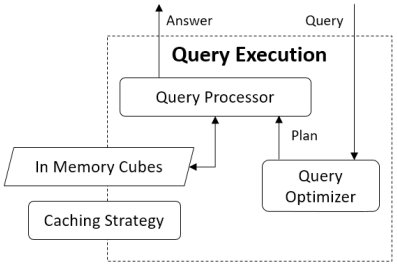

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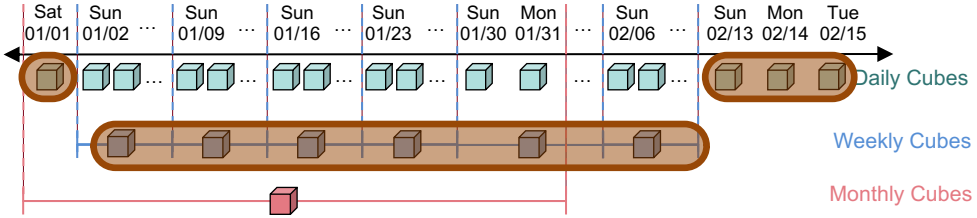

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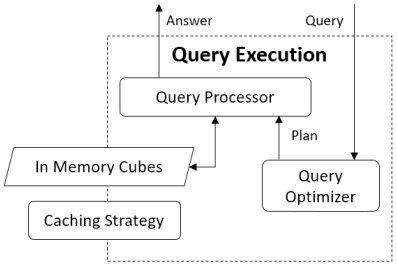

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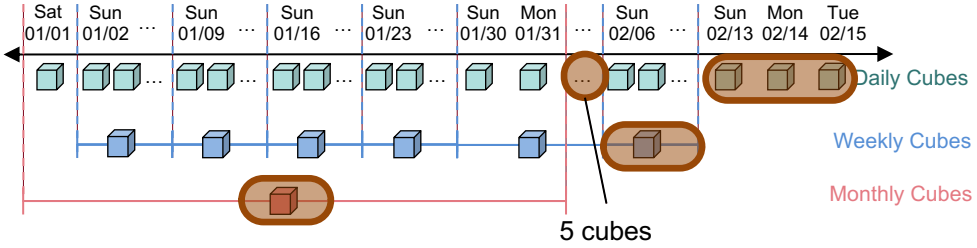

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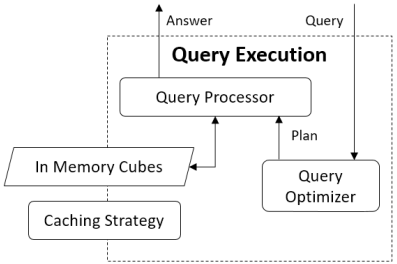

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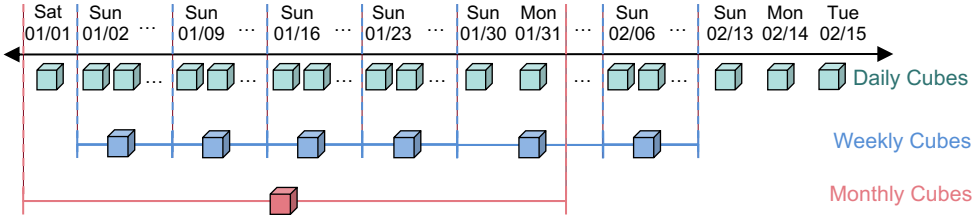

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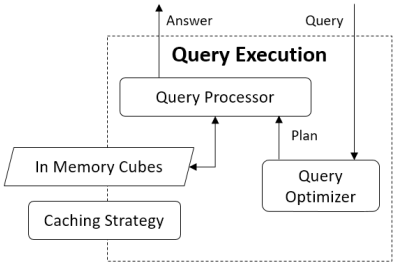

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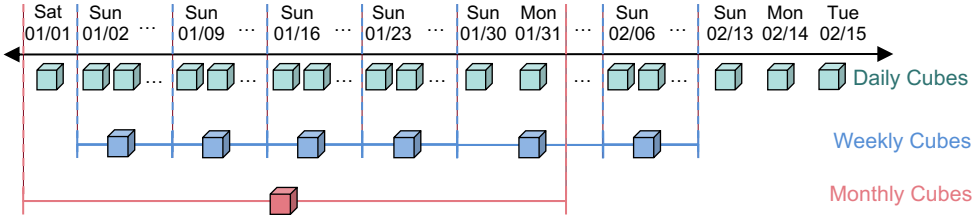

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Cache Awareness

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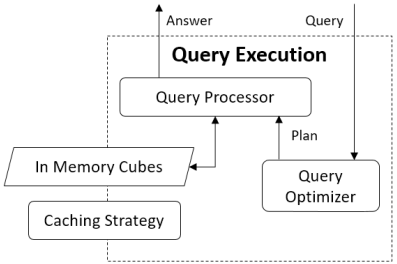

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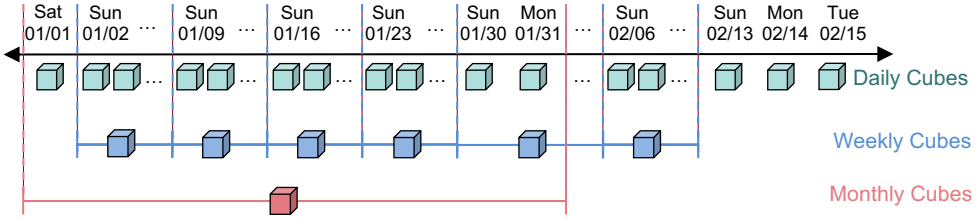

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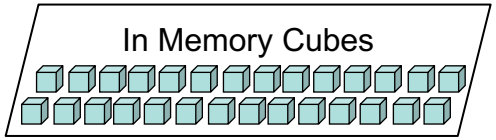

E.g. $\alpha = 1$

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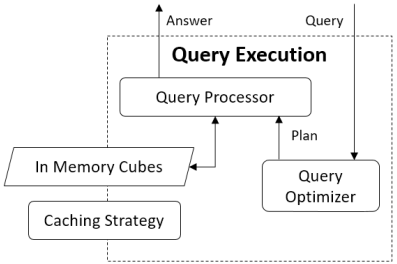

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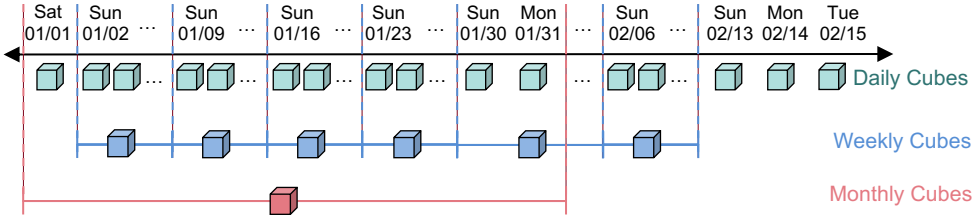

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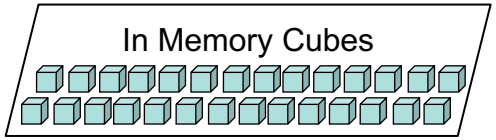

E.g. $\alpha = 1$

A- All daily	**cost = 0 disk I/O**
B- 6 weekly + 4 daily	**cost = 6 disk I/O**
C- 1 monthly + 1 weekly + 8 daily	**cost = 2 disk I/O**

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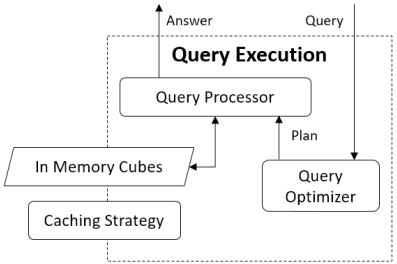

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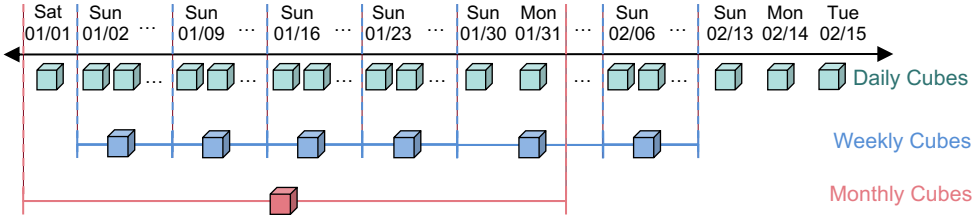

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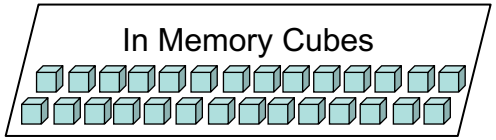

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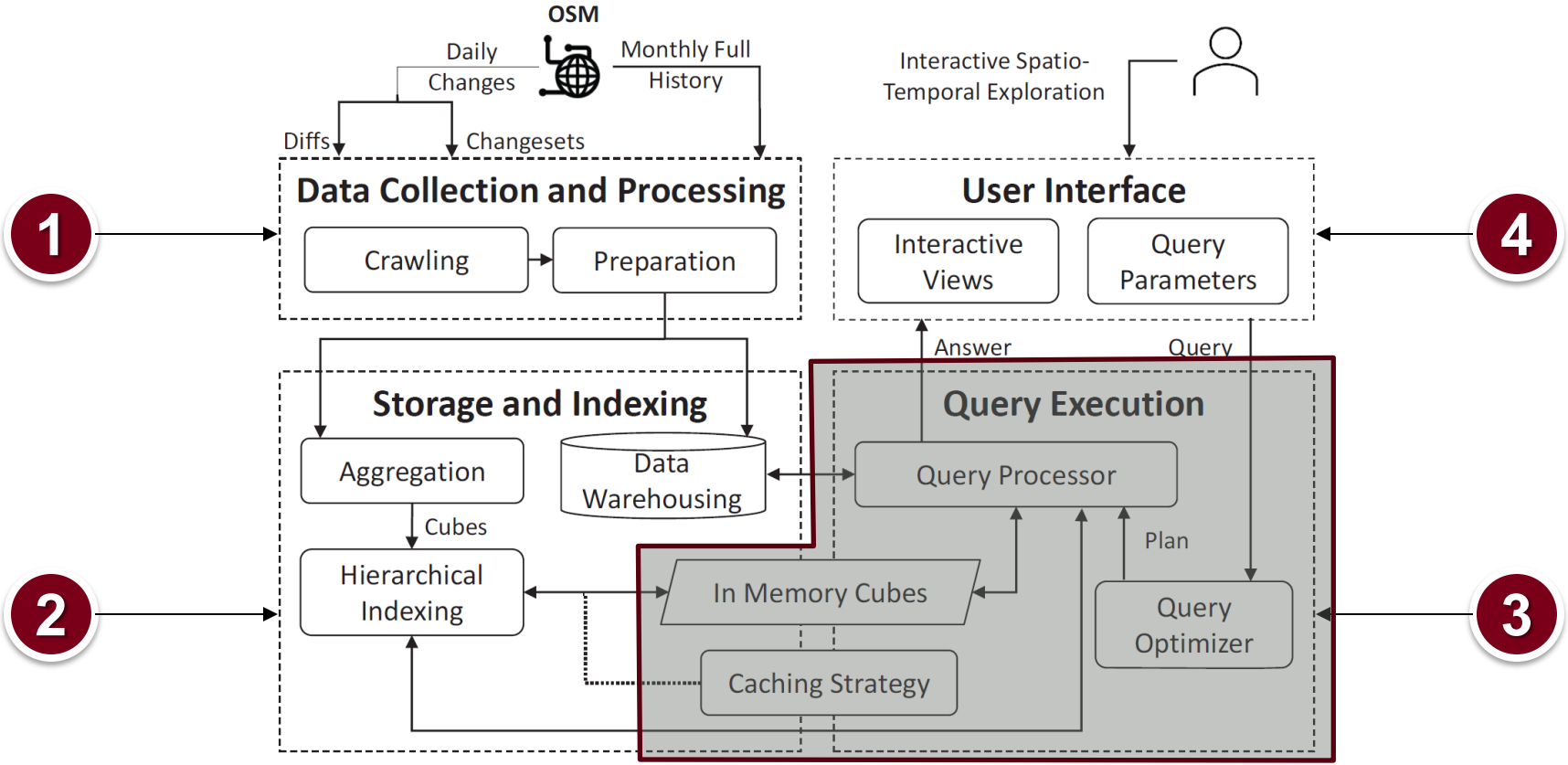
RASED Architecture



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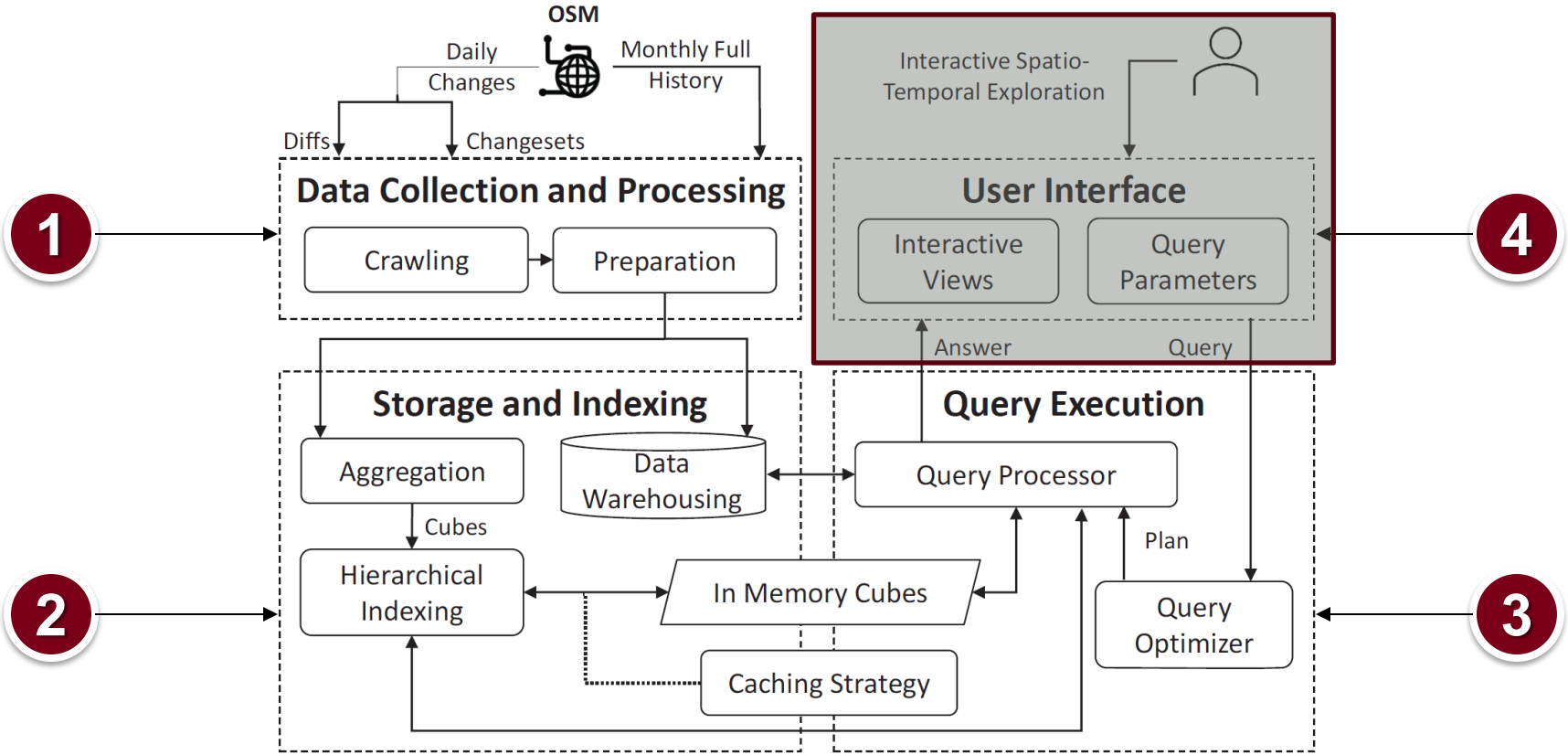

3- User Interface

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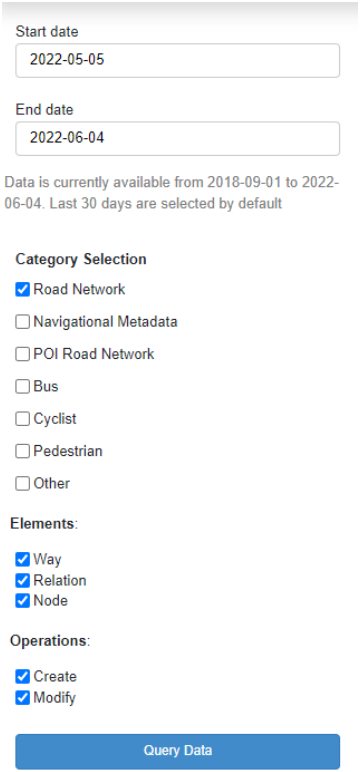
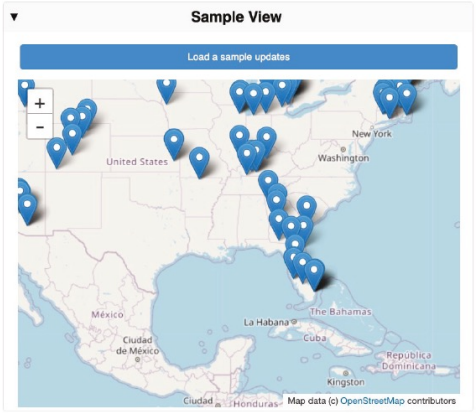
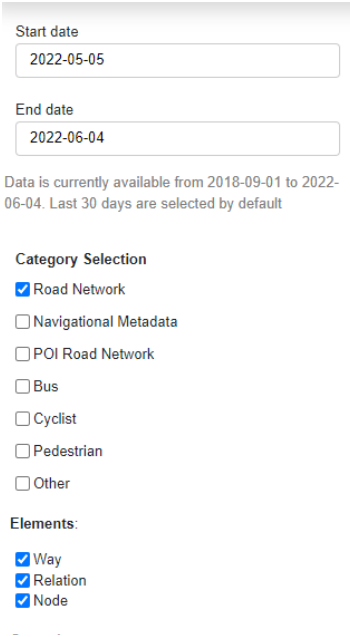
- **Input**: Query Parameters

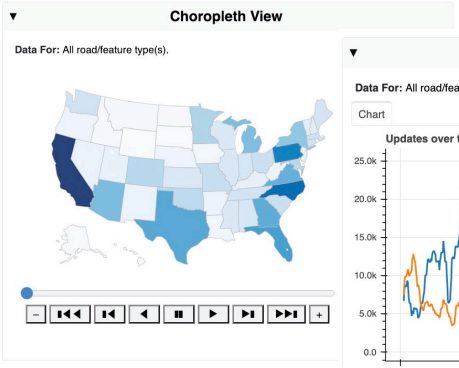


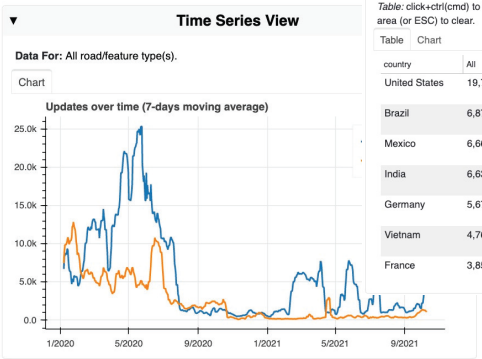
3- User Interface

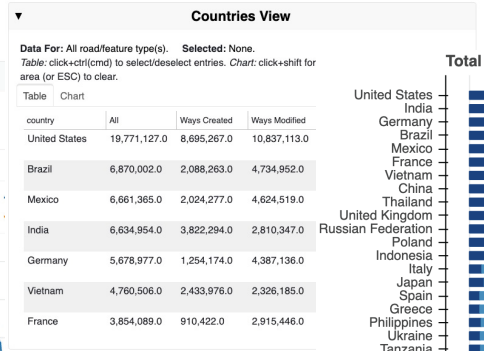
- **Input**: Query Parameters
- **Output**:
  - Statistics either absolute numbers or percentages
  - Visualizations as:
    - Tabular format sorted on any column,
    - Various charts (bar, choropleth, time series)
    - Time-lapse video showing the road network evolution

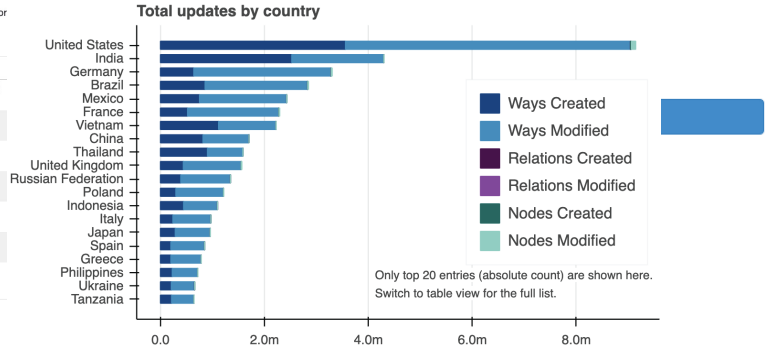












Outline

1. **Motivation**
2. **Background**
   - Map updates, Datasets, and Queries
3. **RASED Architecture & Main Modules**
   - Data Collection & Processing
   - Storage & Indexing
   - Query Execution
   - User Interface
4. **Experimental Results**
5. **RASED in Action (quick demo)**

Setting RASED Parameters

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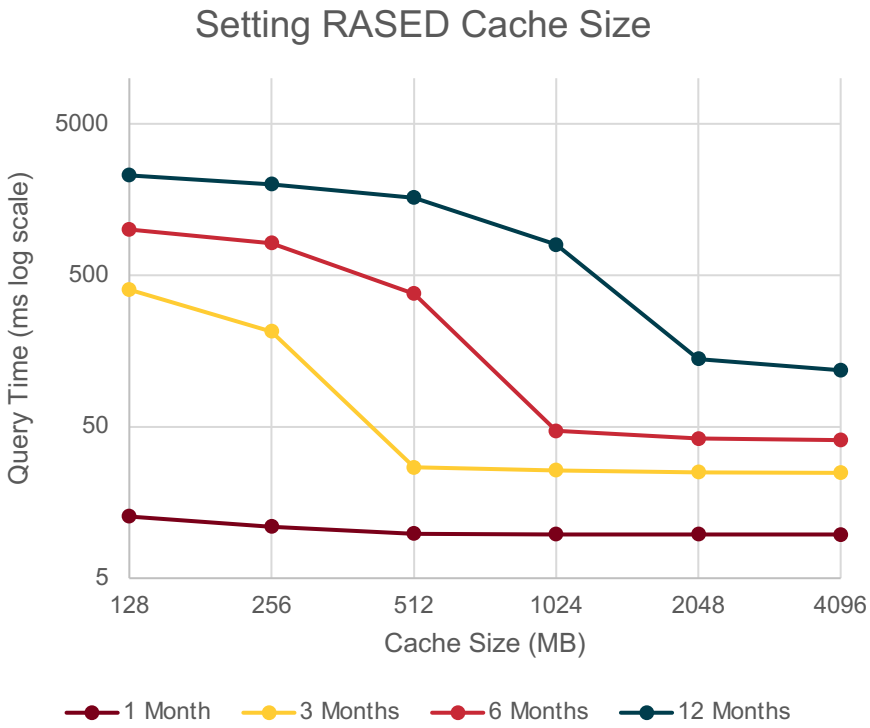

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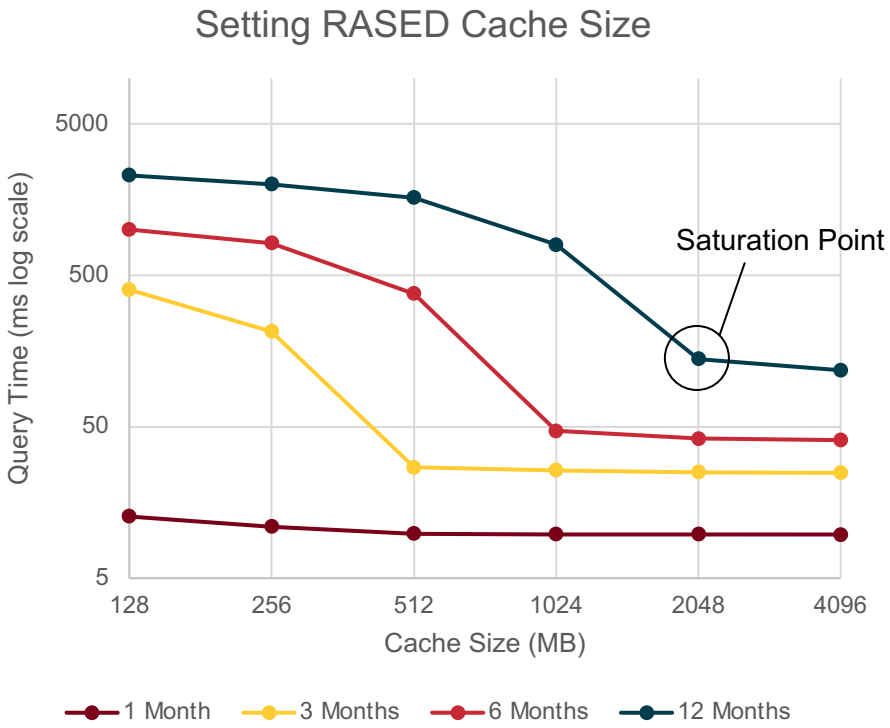

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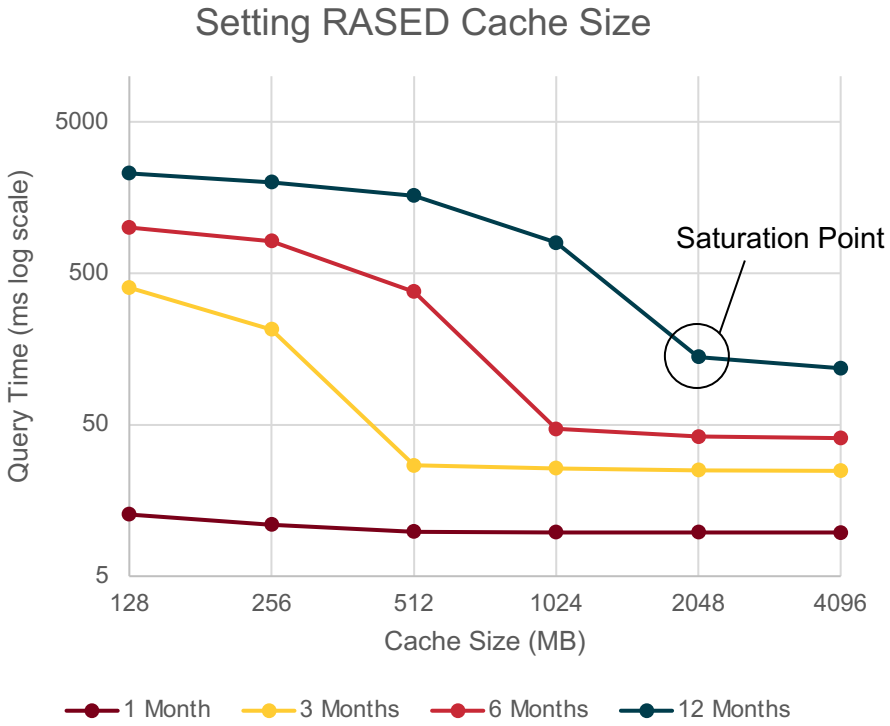

RASED Uses 2048 MB for Cache

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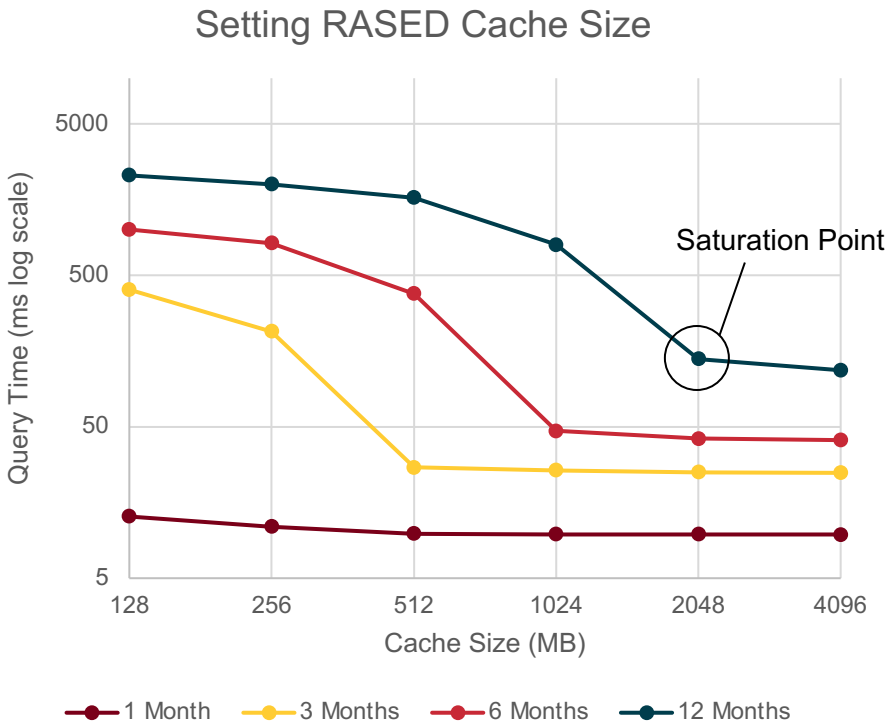

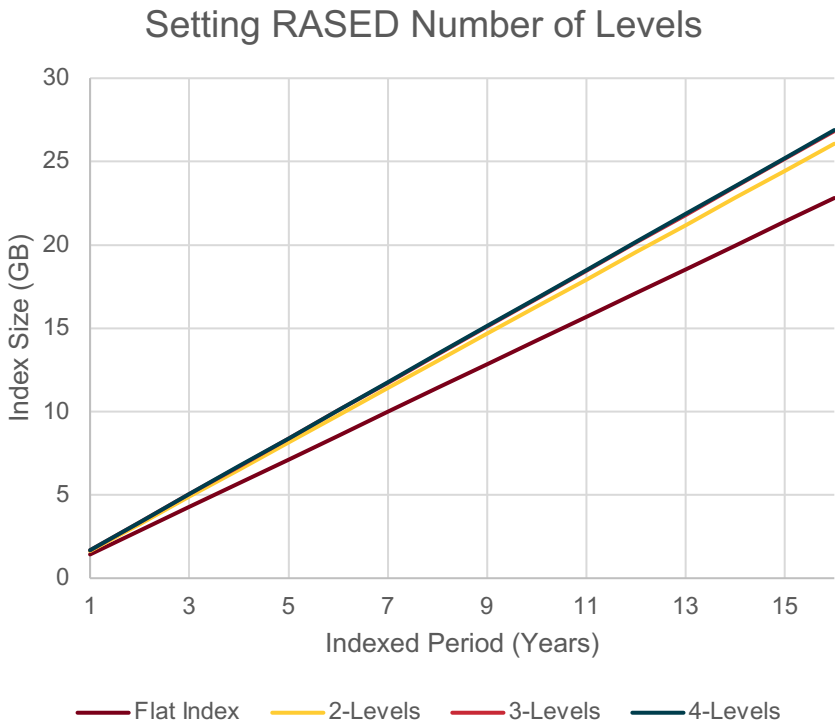

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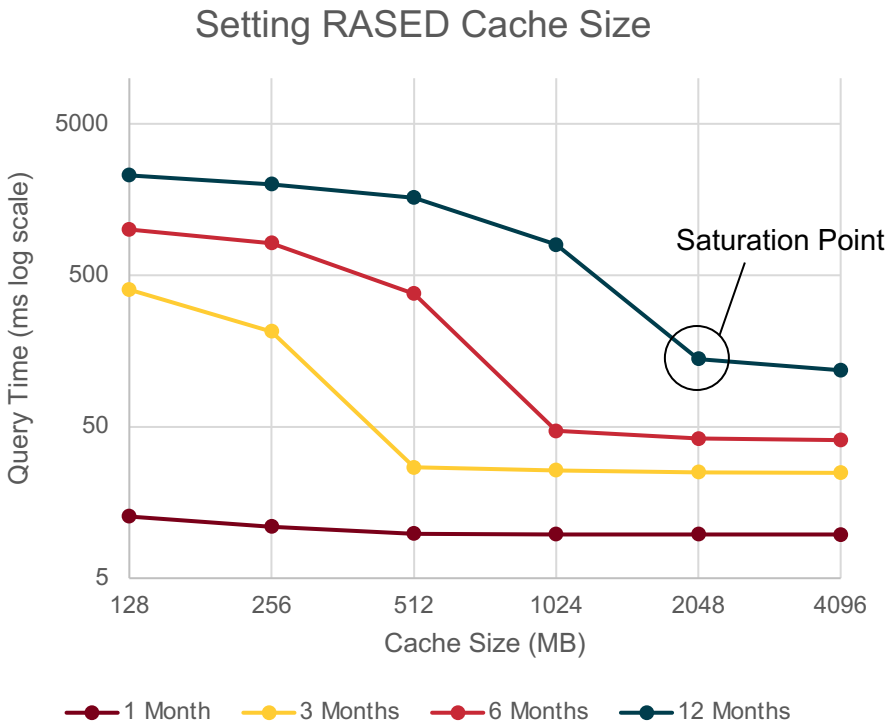

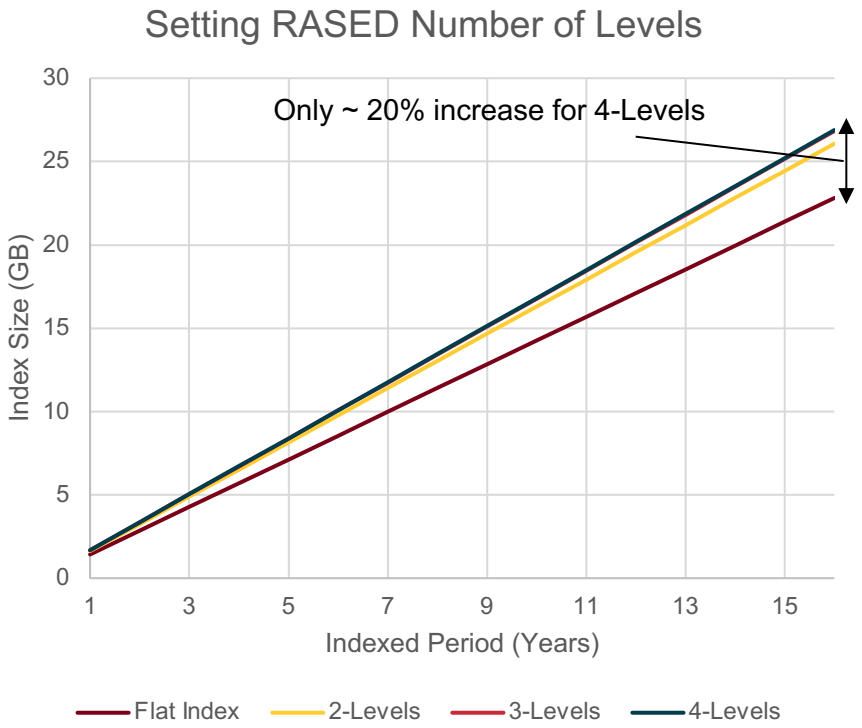

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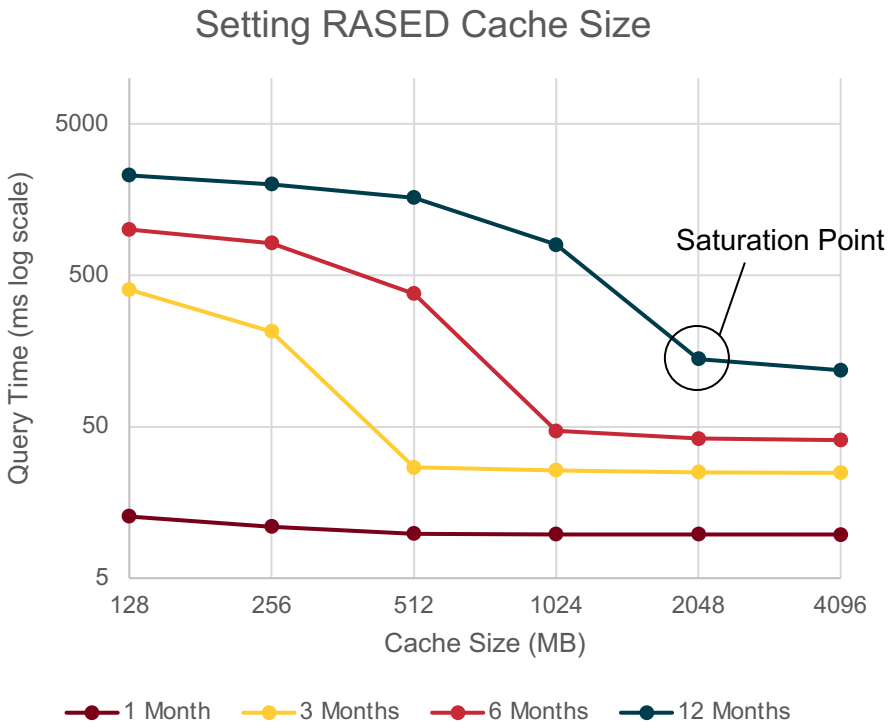

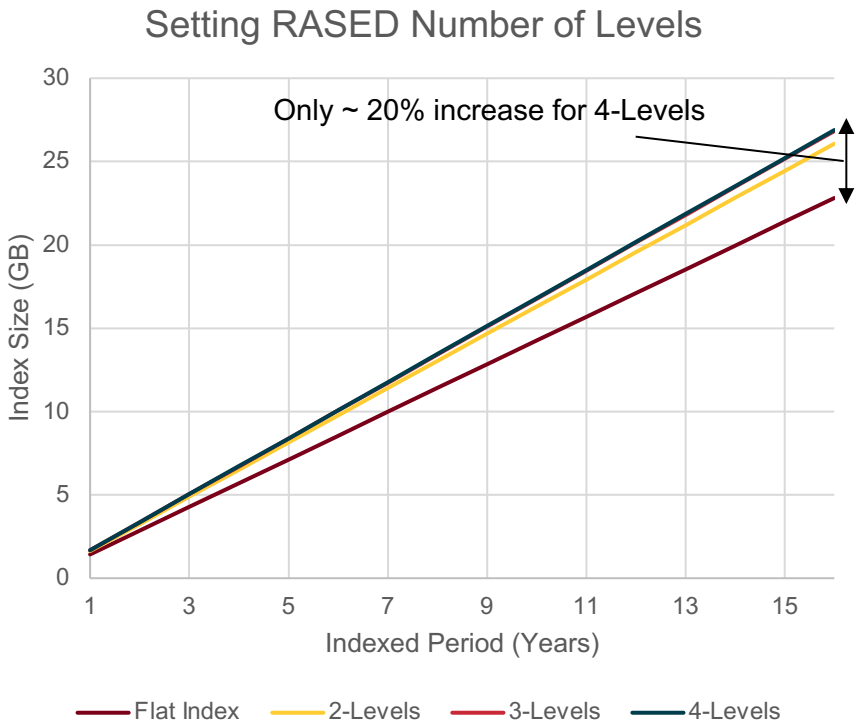

RASED Uses 2048 MB for Cache

RASED Index Uses 4 Levels

RASED Performance

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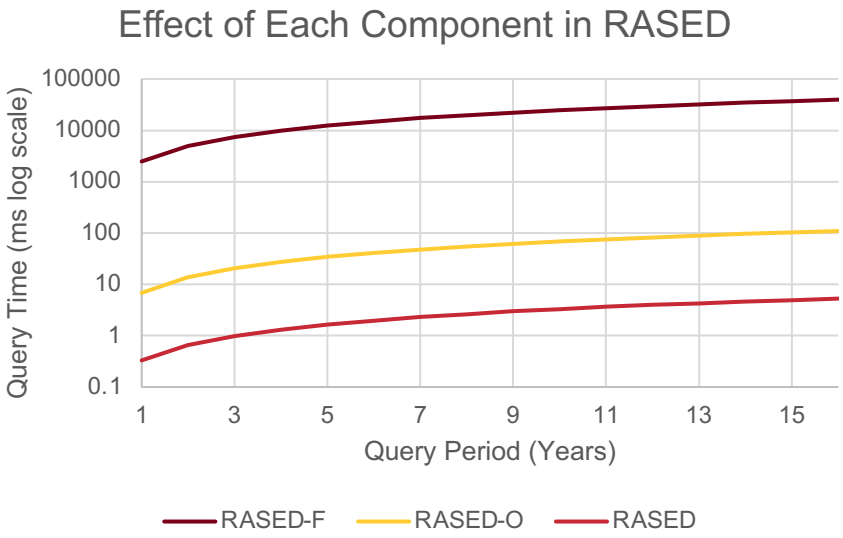

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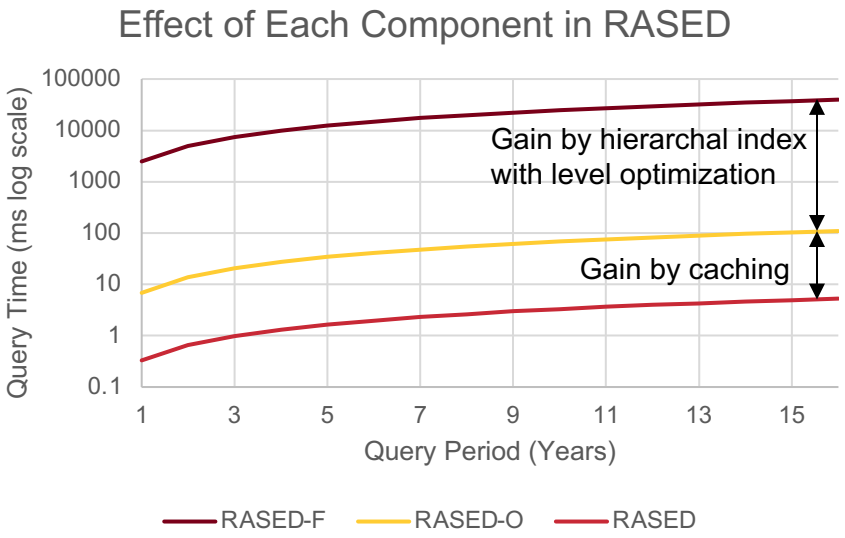

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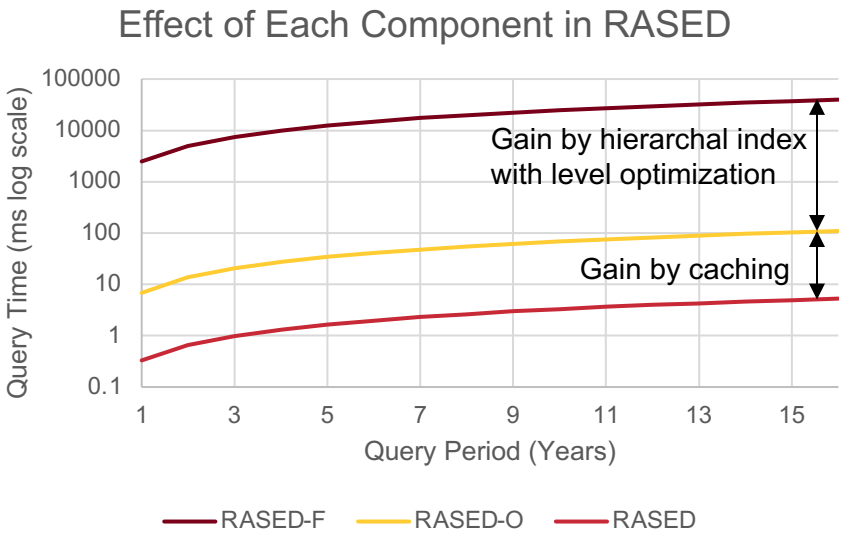

RASED indexing, optimizing, and caching reduce response times by orders of magnitude

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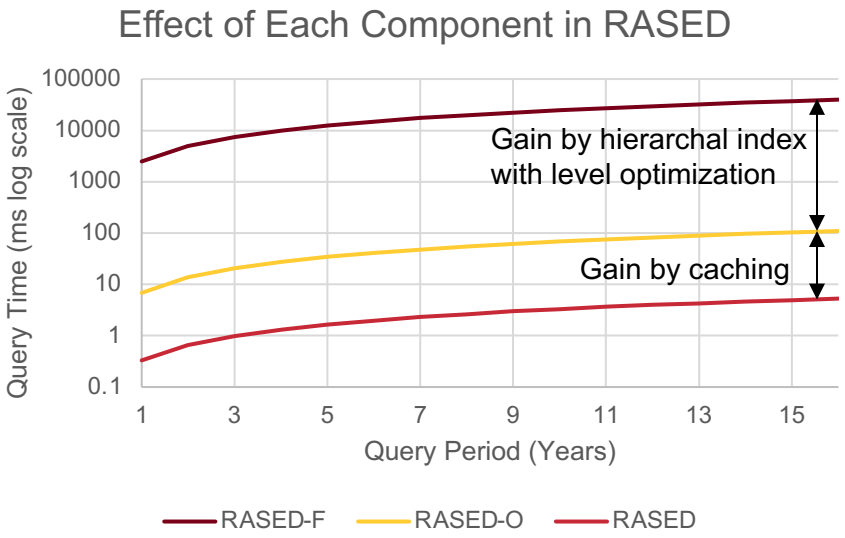
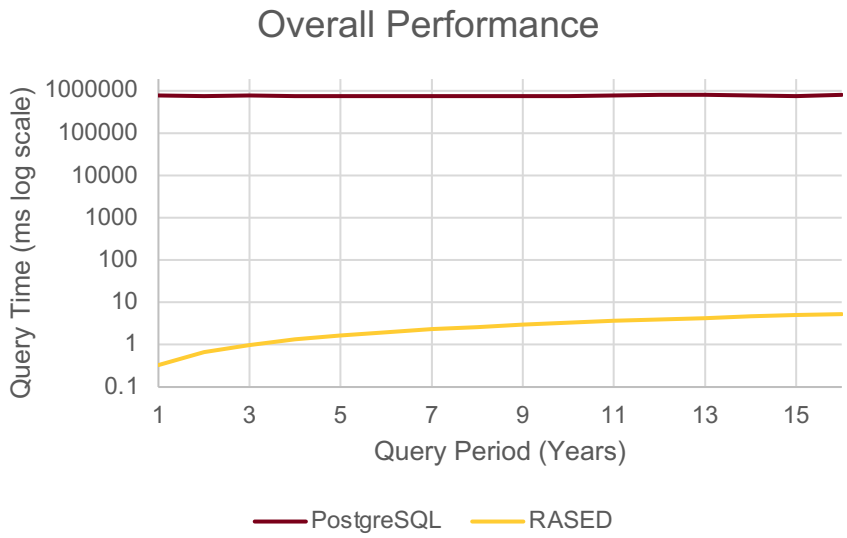
PostgreSQL constantly requires scanning the whole data because query involves multiple attributes in the Group By clause





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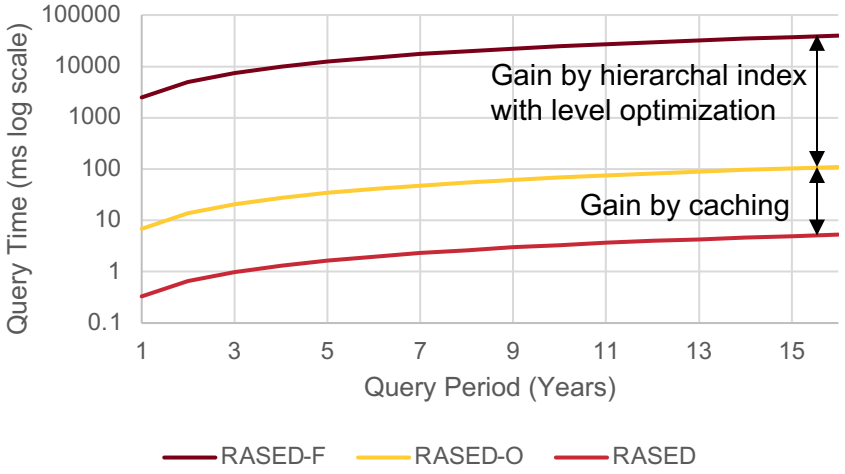
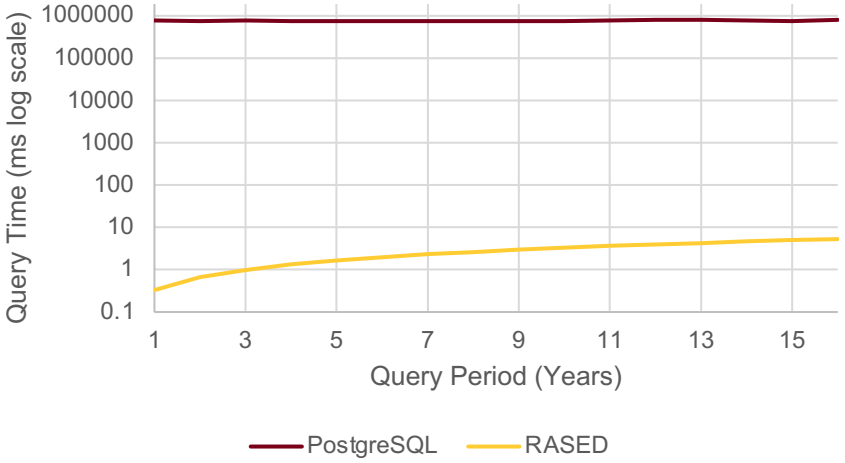


RASED indexing, optimizing, and caching reduce response times by orders of magnitude

Overall Performance



RASED queries are always answered in milliseconds

Outline

1. **Motivation**
2. **Background**
   - Map updates, Datasets, and Queries
3. **RASED Architecture & Main Modules**
   - Data Collection & Processing
   - Storage & Indexing
   - Query Execution
   - User Interface
4. **Experimental Results**
5. **RASED in Action (quick demo)**

DEMO

https://rased.cs.umn.edu

https://www.youtube.com/watch?v=fB2JxTZ60wU

THANK YOU