QAWARE SOFTWARE ENGINEERING

FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
TECHNISCHE FAKULTÄT

Chronix: Long Term Storage and Retrieval Technology for Anomaly Detection in Operational Data

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Detecting Anomalies in Running Software matters

Various kinds of anomalies:

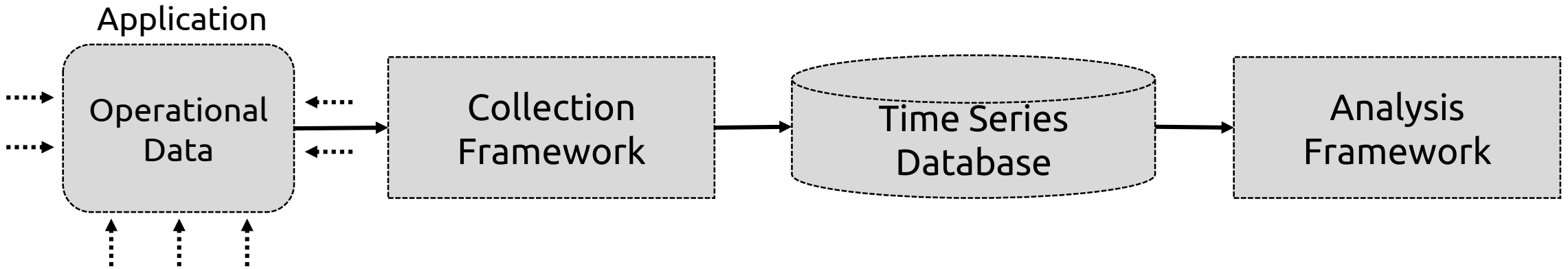
- **Resource consumption**: anomalous memory consumption, high CPU usage, …
- **Sporadic failure**: blocking state, deadlock, dirty read, …
- **Security**: port scanning activity, short frequent login attempts, …

➥ **Economic or reputation loss.**

Detection is a complex task:

- **Multiple components**: Database, Service Discovery, Configuration Service, …
- **Different technologies**: Go, Java, Java-Script, Python, …
- **Various transport protocols**: HTTP, Protocol Buffers, Thrift, JSON, …

Anomaly Detection Tool Chain for Operational Data



Types of operational data:

- **Metrics:** scalar values, e.g., rates, runtimes, total hits, counters, …
- **Events:** single occurrences, e.g., a user's login, product order, …
- **Traces:** sequences within a software system, e.g., the called methods, …

Anomaly Detection Tool Chain for Operational Data

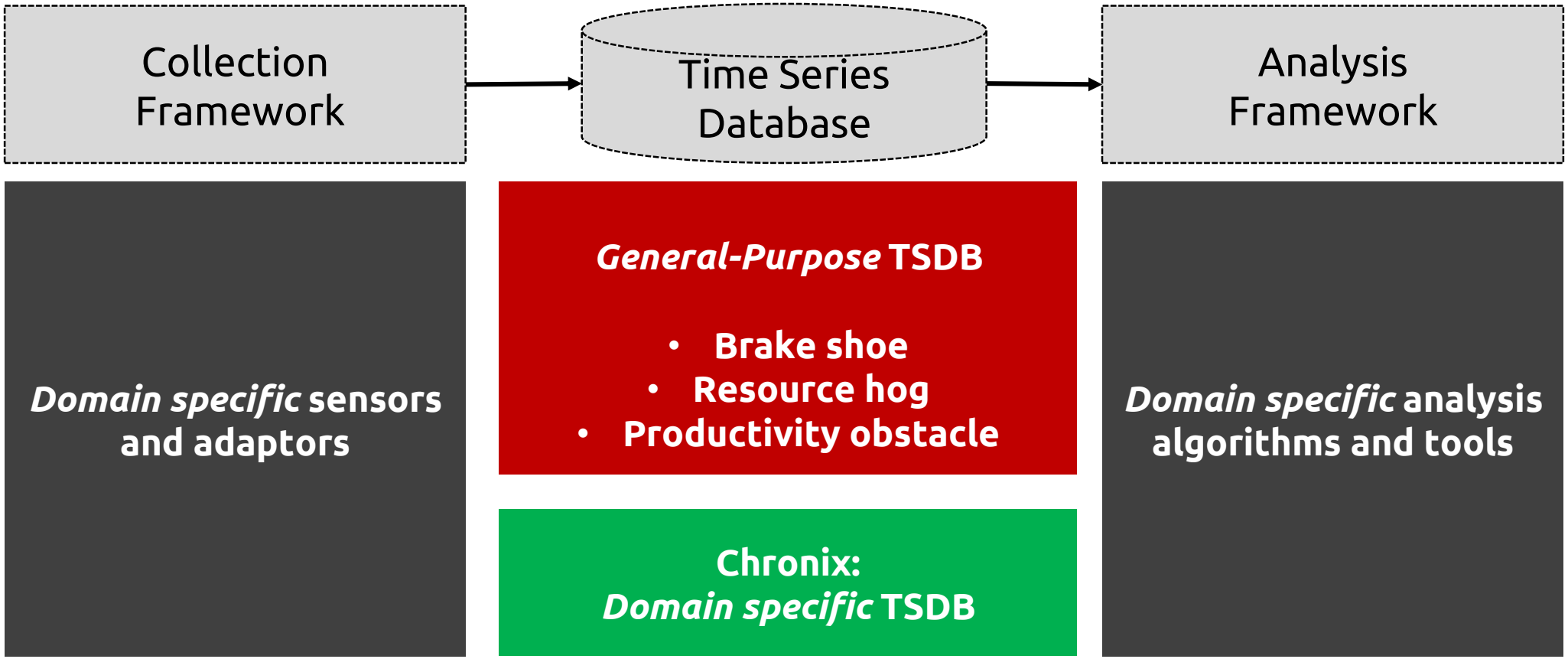
Collects operational data from a running application

Stores the time series data

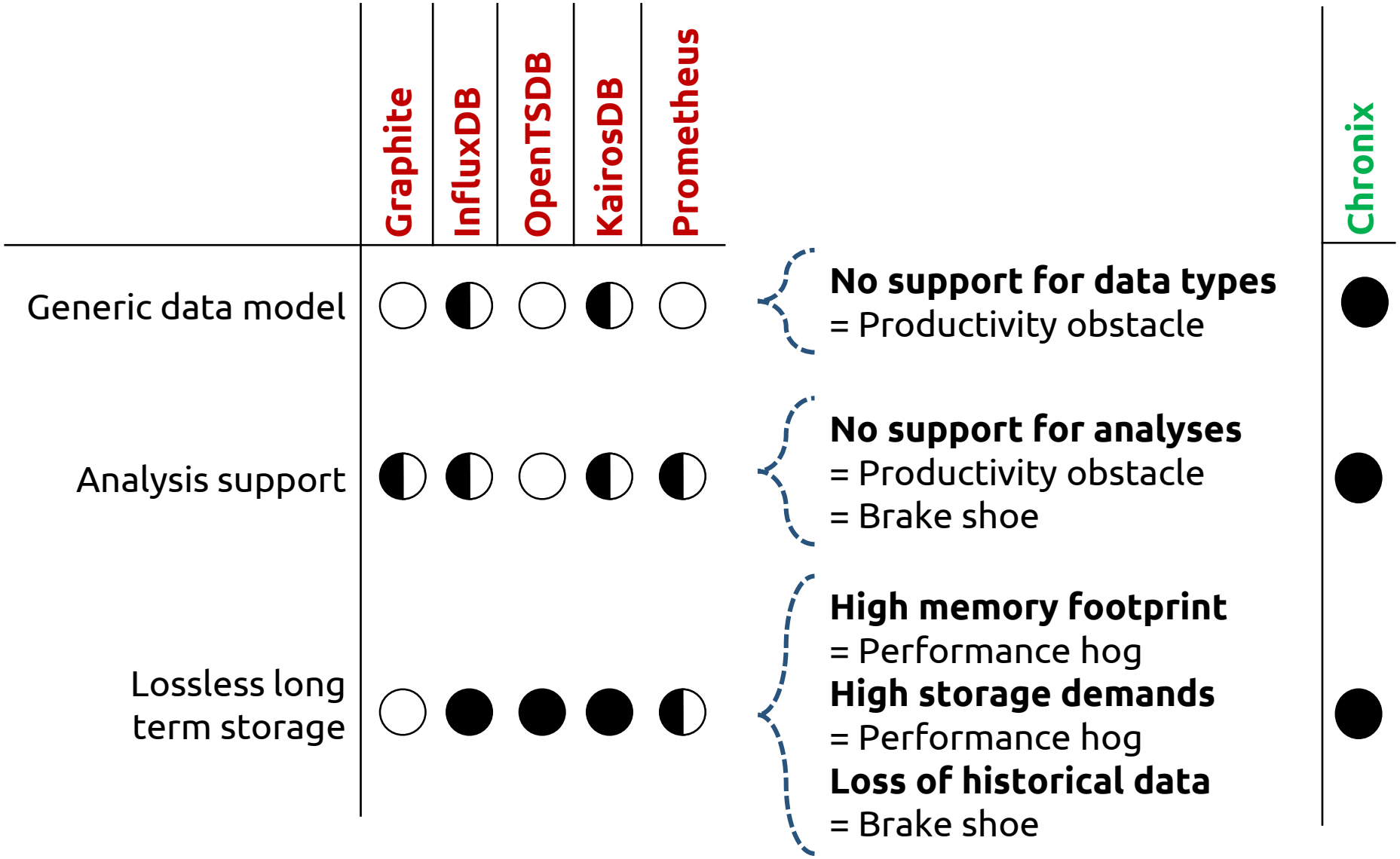
Timestamp	V1	V2
25.10.2016 00:00:01.546	218.34	51
…	…	…

Asks the database for data and analyzes the data

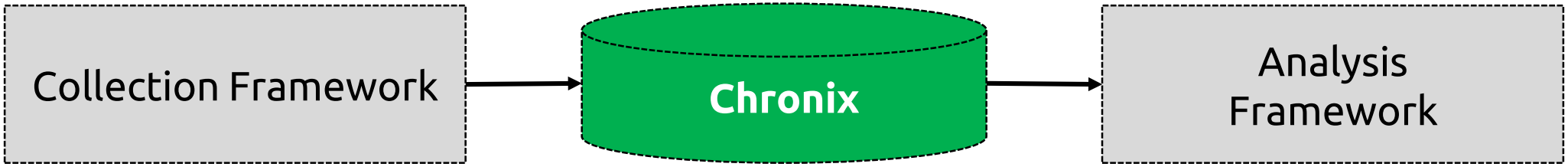
Anomaly Detection Tool Chain for Operational Data



State of the art: General-purpose TSDBs in Anomaly Detection

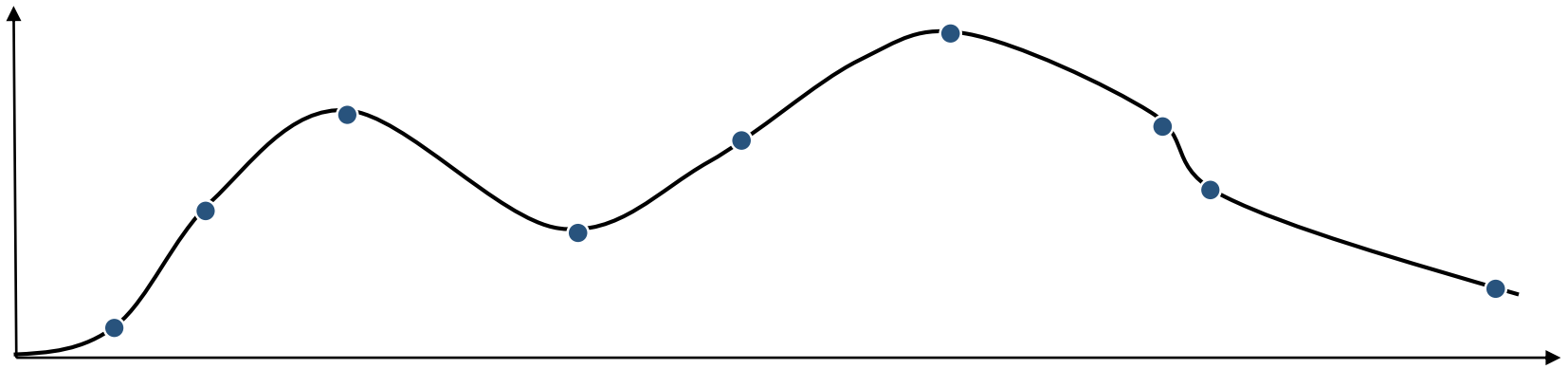


7 Bullets for the domain of Anomaly Detection



1. Option to pre-compute an extra representation of the data
2. Optional timestamp compression for almost-periodic time series
3. Records that meet the needs of the domain
4. Compression technique that suits the domain's data
5. Underlying multi-dimensional storage
6. Domain specific query language with server-side evaluation
7. Domain specific commissioning of configuration parameters

Running Example: Almost-periodic time series with operational data



Timestamp	Value	Metric	Process	Host
25.10.2016 00:00:01.546	218.34	ingester\time	SmartHub	QAMUC
25.10.2016 00:00:06.718	218.37	ingester\time	SmartHub	QAMUC
25.10.2016 00:00:11.891	218.49	ingester\time	SmartHub	QAMUC
25.10.2016 00:00:16.964	218.52	ingester\time	SmartHub	QAMUC
…	…	…	…	…
…	…	…	…	…

Option to pre-compute data to speed up analyses

Timestamp	Value	Metric	Process	Host	SAX
25.10.2016 00:00:01.546	218.34	ingester\time	SmartHub	QAMUC	A
25.10.2016 00:00:06.718	218.37	ingester\time	SmartHub	QAMUC	B
25.10.2016 00:00:11.891	218.49	ingester\time	SmartHub	QAMUC	C
25.10.2016 00:00:16.964	218.52	ingester\time	SmartHub	QAMUC	D
…	…	…	…	…	…
…	…	…	…	…	…

- Chronix is **lossless**: it keeps all details because the analyses are ad-hoc and may need them.
- Chronix offers a `programming interface` for adding extra domain specific “columns”. Examples: Fourier transformation, Symbolic Aggregate approXimation (SAX), etc.
- Added “columns” speed up anomaly detection queries.

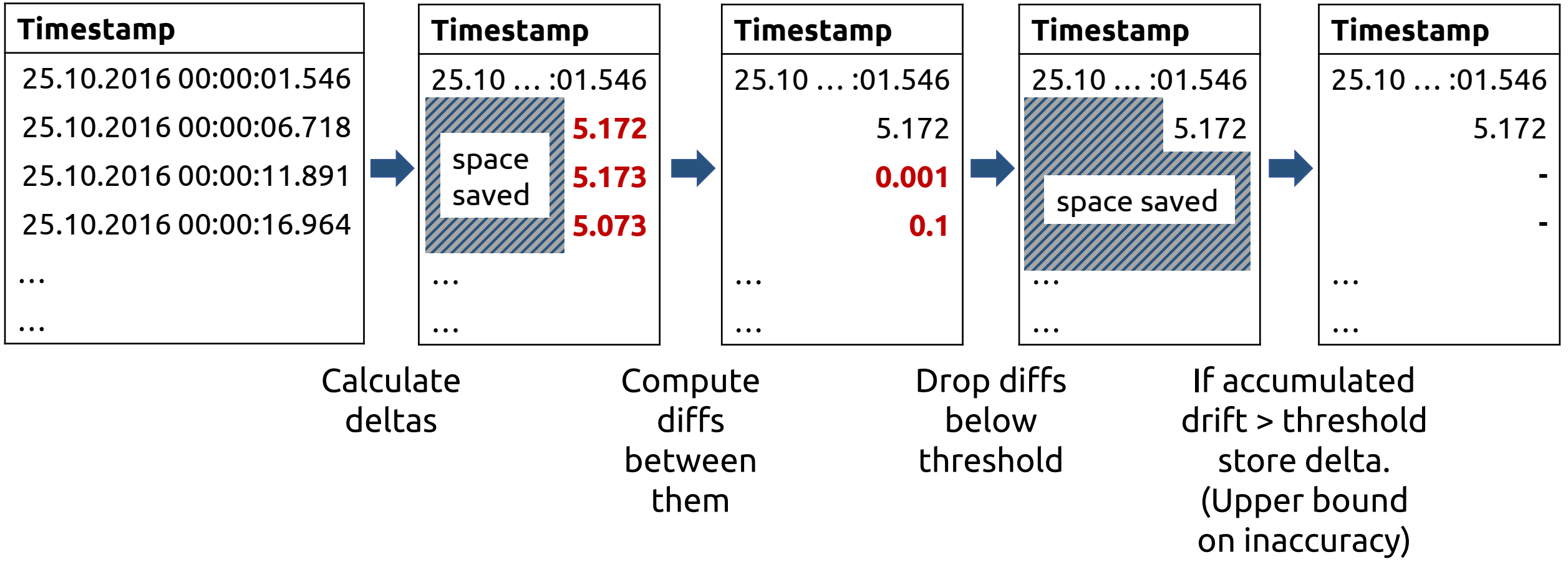
Optional timestamp compaction

Timestamp	Value	Metric	Process	Host	SAX
25.10.2016 00:00:01.546	218.34	ingester\time	SmartHub	QAMUC	A
5.172	218.37	ingester\time	SmartHub	QAMUC	B
-	218.49	ingester\time	SmartHub	QAMUC	C
Space saved -	218.52	ingester\time	SmartHub	QAMUC	D
	…	…	…	…	…
	…	…	…	…	…

- It suffices to be able to reconstruct approximate timestamps for almost-periodic time series.
- **Date-Delta-Compaction**
- Chronix is **functionally lossless** as it keeps all *relevant* details.

- The tolerable degree of inaccuracy is a Configuration Parameter of

Date-Delta-Compaction



Domain specific data characteristics

Timestamp	Value	Metric	Process	Host	SAX
25.10.2016 00:00:01.546	218.34	ingester\time	SmartHub	QAMUC	A
5.172	218.37	ingester\time	SmartHub	QAMUC	B
-	218.49	ingester\time	SmartHub	QAMUC	C
-	218.52	ingester\time	SmartHub	QAMUC	D
	…	…	…	…	…
		…	…	…	…

Many anomaly detection tasks need blocks of data rather than “lines”.

Some compression techniques work better than others.

“Columns” with repetitive values.

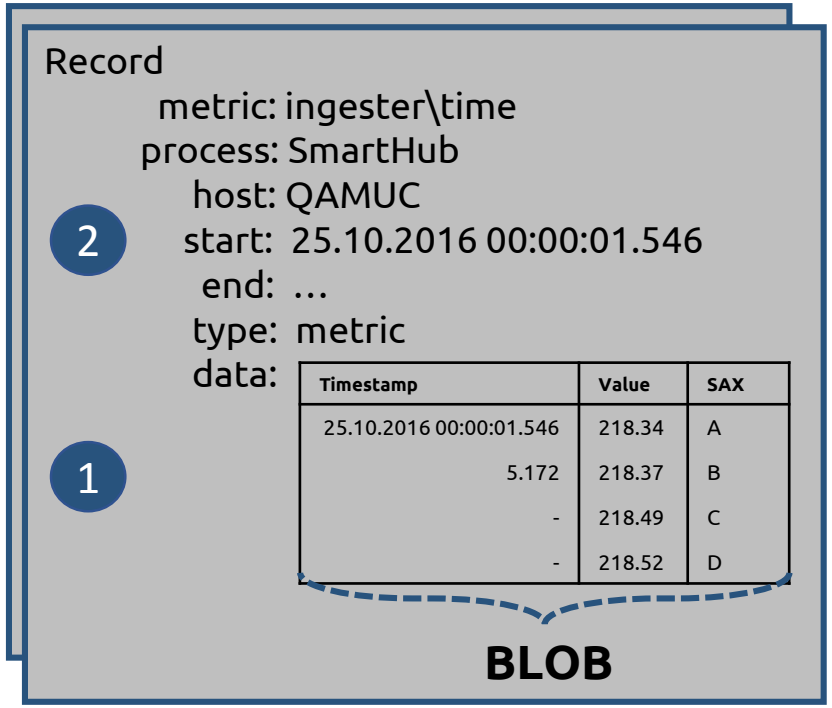
3 Records that meet the needs of the domain

Therefore:

Record := Attributes + Start + End + Type + Data Chunk

Timestamp	Value	Metric	Process	Host	SAX
25.10.2016 00:00:01.546	218.34	ingester\time	SmartHub	QAMUC	A
5.172	218.37	ingester\time	SmartHub	QAMUC	B
-	218.49	ingester\time	SmartHub	QAMUC	C
-	218.52	ingester\time	SmartHub	QAMUC	D
1 …	… 1	2	2	2	1
…	…	…	…	…	…

chunk & convert



- Chronix offers a `programming interface` to implement time series specific records.
- Chronix exploits repetitiveness and bundles “lines” into data chunks.

- The chunk size is a Configuration Parameter of 7

Compression technique that suits the domain's data

Record
metric: ingester\time
process: SmartHub
host: QAMUC
start: 25.10.2016 00:00:01.546
end: …
type: metric
data:

Timestamp	Value	SAX
25.10.2016 00:00:01.546	218.34	A
5.172	218.37	B
-	218.49	C
-	218.52	D

serialize & compress

Record
metric: ingester\time
process: SmartHub
host: QAMUC
start: 25.10.2016 00:00:01.546
end: …
type: metric
data: **00105e0 e6b0 343b 9c74 080 7bc 0804 e7d5 0804 00105f0**

Compressed BLOB

- Chronix exploits that domain data often has small increments, recurring patterns, etc.
- Chronix uses a lossless compression technique that minimizes (record sizes + index sizes).

- The choice of compression technique is a Configuration Parameter of

Underlying multi-dimensional storage

Record
metric: **ingester\time**
process: SmartHub
host: **QAMUC**
start: 25.10.2016 00:00:01.546
end: …
type: **metric**
data: 00105e0 e6b0 343b 9c74 080
7bc 0804 e7d5 0804 00105f0

Record
metric: **ingester\methods**
process: SmartHub
host: **QAMUC**
start: 25.10.2016 00:00:01.546
end: …
type: **trace**
data: d65fa01 7ab2 433c 7c8e f123
2ca 0713 a8f5 926b 01006e1

```
q=host:QAMUC AND metric:ingester*
  AND type:[metric OR trace]
  AND end:NOW-7MONTH
```

By using a multi-dimensional storage …

- … Chronix supports explorative analyses.
  - Attributes are visible to the storage and indexed.
  - Users can use any combination to find a record.
- … Chronix supports correlating analyses.
  - Every type of data can be stored.
  - Queries can use and combine types.

Domain specific query language with server-side evaluation

Basic	Graphite	InfluxDB	OpenTSDB	KairosDB	Prometheus	Chronix
distinct	×	✓	×	×	×	✓
integral	✓	×	×	×	×	✓
min/max/sum	✓	✓	✓	✓	✓	✓
count	×	✓	✓	✓	✓	✓
avg/median	✓	✓	✓	✓	✓	✓
bottom/top	×	✓	×	×	✓	✓
first	✓	✓	×	✓	×	✓
last	✓	✓	×	✓	×	✓
percentile (p)	✓	✓	✓	✓	✓	✓
stddev	✓	✓	✓	✓	✓	✓
derivative	✓	✓	×	✓	✓	✓
nnderivative	✓	✓	×	×	×	✓
diff	×	✓	×	✓	✓	✓
movavg	✓	✓	×	×	×	✓
divide/scale	✓	✓	×	✓	✓	✓
High-level						
sax [33]	×	×	×	×	×	✓
fastdtw [38]	×	×	×	×	×	✓
outlier	×	×	×	×	×	✓
trend	×	×	×	×	×	✓
frequency	×	×	×	×	×	✓
grpsize	×	×	×	×	×	✓
split	×	×	×	×	×	✓

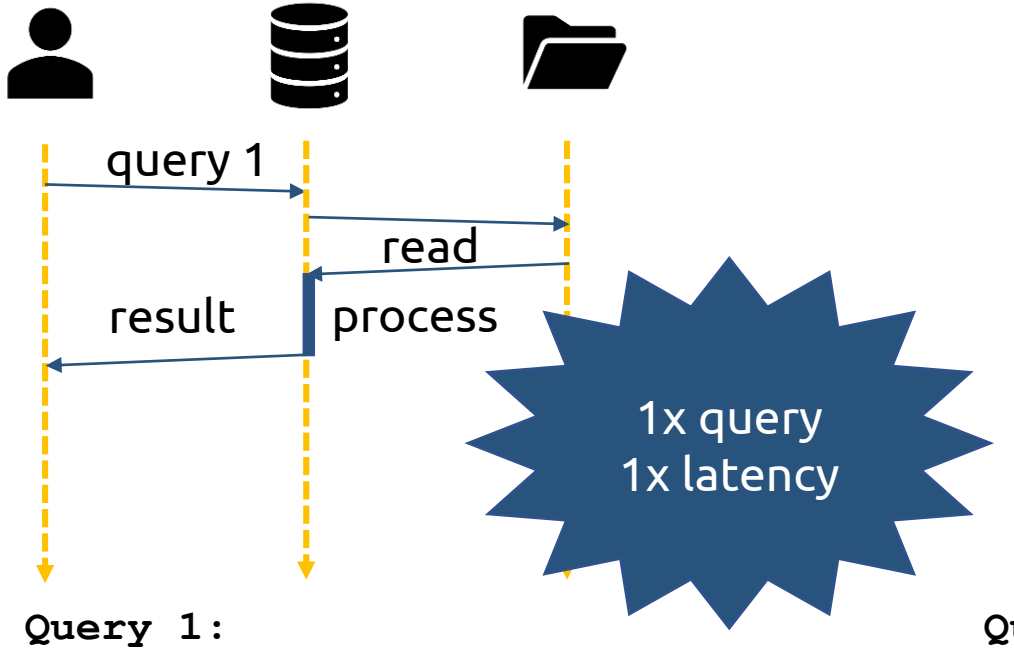
basic functions

also needed for anomaly detection

- Chronix offers not just basic functions but also high-level built-in domain specific analysis functions.
- Chronix evaluates functions server-side for speed.
- Chronix offers a **`plug-in interface`** to add functions.

Domain specific query language with server-side evaluation

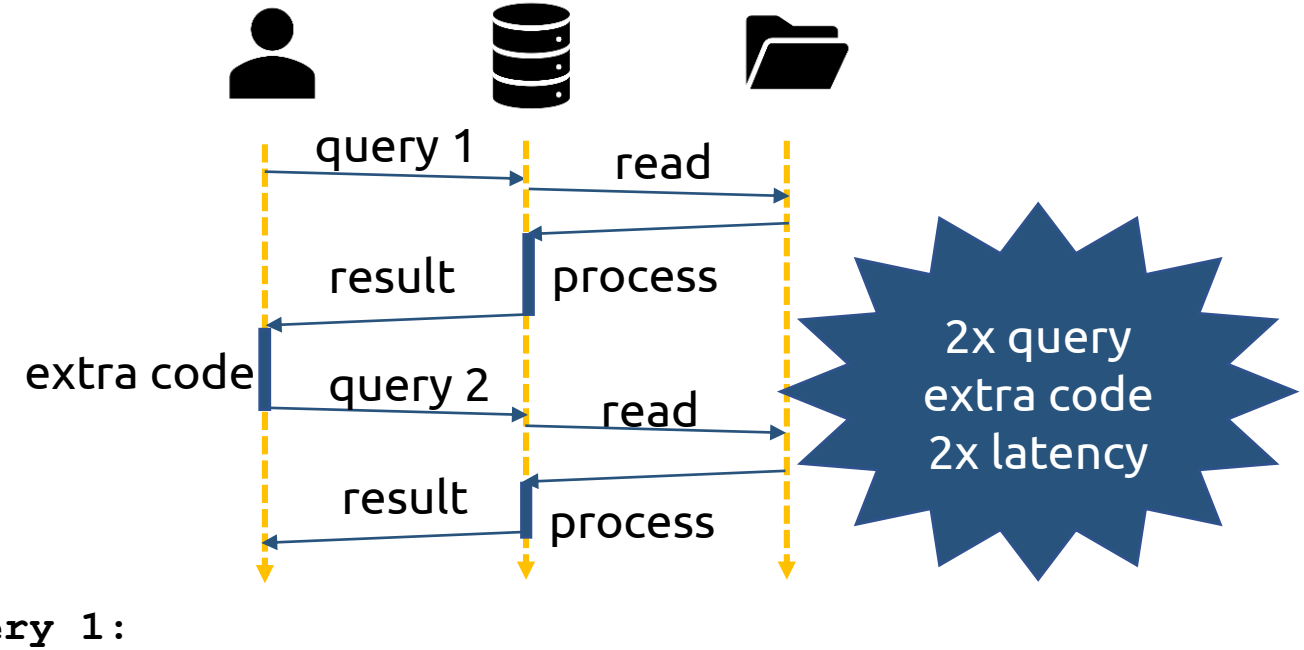
Chronix




```
Query 1:
 q=metric:ingester\time
 & cf=outlier
```

high-level function

General-Purpose Time Series Database




```
Query 1:
 select q(0.25,time),q(0.75,time) from ingester

Calculate threshold

Query 2:
 select time from ingester where time >= threshold
```

extra code

- Chronix achieves more programming comfort & fast results.

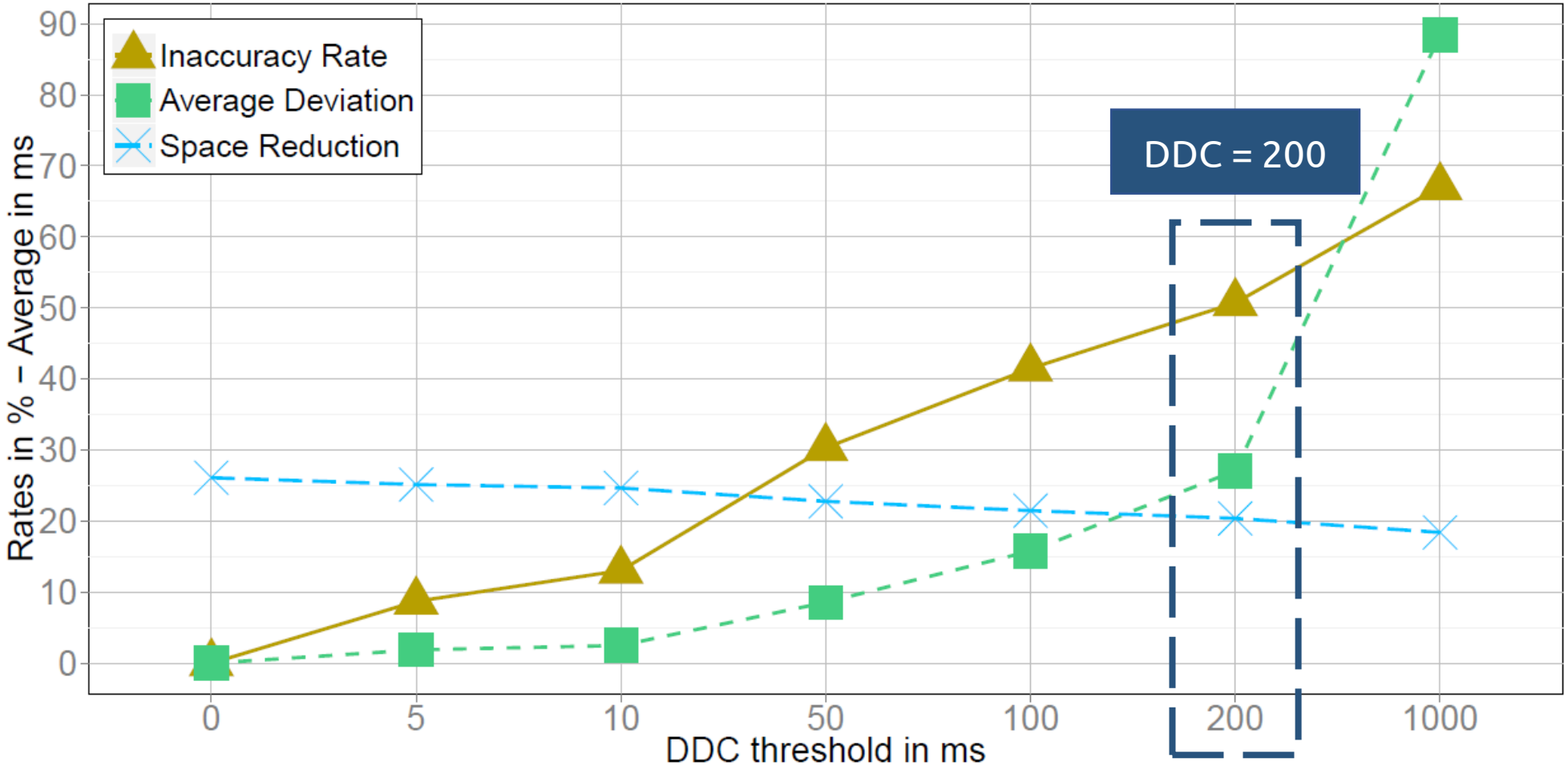
Operational data of 5 industry projects

	Description	Interval (sec)	Pairs (mio)	Time series
P1	Application for searching car maintenance and repair instructions. (8 app sever, 20 search server)	30	2,4	1,080
P2	Retail application for orders, billing, and customer relations. (1 database, 2 app server)	60	331.4	8,567
P3	Sales application of a car manufacturer. (1 database, 2 app servers)	30	162.6	4,538
P4	Service application for modern cars (music streaming)	1	metric 3.9 lsof 0.4 strace 12.1	500
P5	Manage the compatibility of software components in a car.	60	3,762.3	24,055
Total			**4,275.1**	**38,740**

used for 

used for the Evaluation

Best threshold for the Date-Delta-Compaction

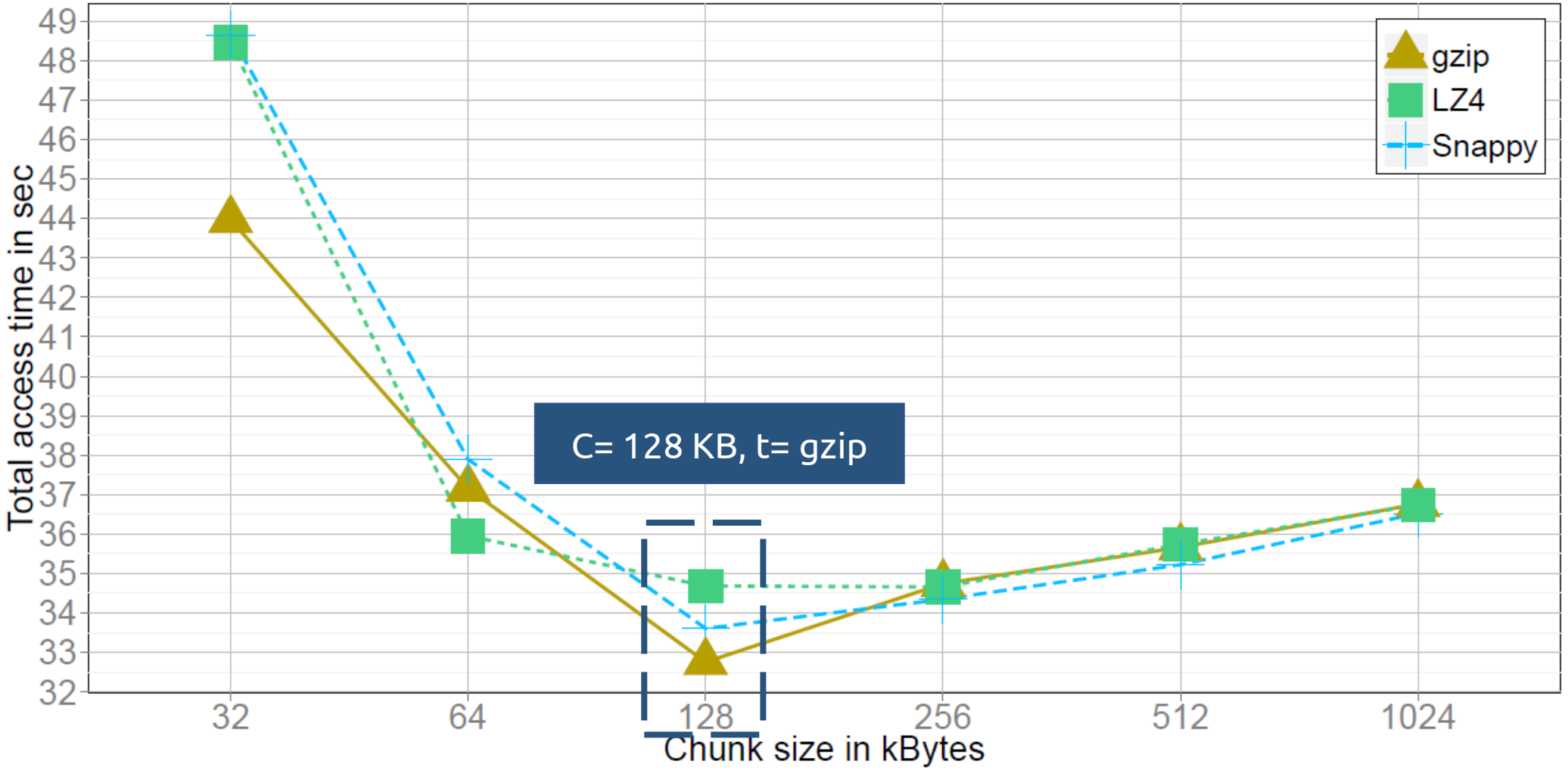


Operational data of 3 (of 5) industry projects

	Description	Interval (sec)	Pairs (mio)	Time series	Query Mix r	Query Mix q
P1	Application for searching car maintenance and repair instructions. (8 app sever, 20 search server)	30	2,4	1,080	91 56 28	2 1 3
P2	Retail application for orders, billing, and customer relations. (1 database, 2 app server)	60	331.4	8,567	21 7	5 30
P3	Sales application of a car manufacturer. (1 database, 2 app servers)	30	162.6	4,538	1 0.5	30 15
P4	…	…	…	…	…	…
P5	…	…	…	…	…	…
Total			**4,275.1**	**38,740**		

r = range (days)
q= # of queries

Best compression technique & Best chunk size for query mix



Operational data of 2 of (5) industry projects ➡ Evaluation

	Description	Interval (sec)	Pairs (mio)	Time series	Query Mix r	q	b	h
P1	…	…	…	…	…	…	…	…
P2	…	…	…	…	…	…	…	…
P3	…	…	…	…	…	…	…	…
P4	Service application for modern cars (music streaming)	1	metric 3.9 lsof 0.4 strace 12.1	500	180 91 56 28	2 2 1 5	2 1 4 4	0 2 3 6
P5	Manage the compatibility of software components in a car.	60	3,762.3	24,055	21 14 7 1 0.5	12 8 15 11 1	2 7 5 6 1	6 8 10 6 2
Total			**4,275.1**	**38,740**				

r = range (days)
q= # of queries
b= # of basis queries
h= # of high-level queries

Quantitative comparison

***General-Purpose* TSDB**

- **Productivity obstacles**
  - **Brake shoe**
  - **Resource hog**

Chronix:
***Domain specific* TSDB**

TSDBs under test	Comparisons
InfluxDB **OpenTSDB** **KairosDB** **Chronix**	a) Memory footprint b) Storage demand c) Data retrieval times d) Query mix runtimes

a) Memory footprint

Memory footprint of the databases (in MB)

	InfluxDB	OpenTSDB	KairosDB	Chronix
Initially after startup (processes up and running)	33	2,726	8,763	446
Maximal memory usage during import	10,336	10,111	18,905	7,002
Maximal memory usage during query	8,269	9,712	11,230	4,792

Chronix has a 34% – 69% smaller memory footprint.

b) Storage demand

Storage demand (in GB)

	Raw data	InfluxDB	OpenTSDB	KairosDB	Chronix
Project 4	1.2	0.2	0.2	0.3	0.1
Project 5	107.0	10.7	16.9	26.5	8.6
total	108.2	10.9	17.1	26.8	8.7

Chronix saves 20% – 68% of the storage space.

c) Data retrieval times

Data retrieval times for 20 · 58 queries (in s)

r	q	InfluxDB	OpenTSDB	KairosDB	Chronix
0.5	**2**	4.3	2.8	4.4	0.9
1	**11**	5.5	5.6	6.6	5.3
7	**15**	34.1	17.4	26.8	7.0
14	**8**	36.2	14.2	25.5	4.0
21	**12**	76.5	29.8	55.0	6.0
28	**5**	7.9	3.9	5.6	0.5
56	**1**	35.4	12.4	24.1	1.2
91	**2**	47.5	15.5	33.8	1.1
180	**2**	96.7	36.7	66.6	1.1
	total	343.8	138.3	248.4	27.1

Chronix saves 80% – 92% on data retrieval times.

d) Query mix runtimes

Runtimes of 20 · 75 b- and h-queries (in s)

	q		InfluxDB	OpenTSDB	KairosDB	Chronix
Basic (b)	4	avg	0.9	6.1	9.8	4.4
	5	max	1.3	8.4	9.1	6.0
	3	min	0.7	2.7	5.3	2.8
	3	stddev.	6.7	16.7	21.1	2.3
	5	sum	0.7	6.0	12.0	2.0
	4	count	0.8	5.5	10.5	1.0
	8	perc.	10.2	25.8	34.5	8.6
High-level (h)	12	outlier	30.7	29.1	117.6	18.9
	14	trend	162.7	50.4	100.6	30.2
	11	frequency	47.3	23.9	45.7	16.3
	3	grpsize	218.9	2927.8	206.3	29.6
	3	split	123.1	2893.9	47.9	37.2
	75	total	604.0	5996.3	620.4	159.3

more important

Chronix saves 73% – 97% of the runtime of analyzing queries.

Chronix unleashes Anomaly Detection tasks

7 domain specific levers to unleash Anomaly Detection

1. Option to pre-compute an extra representation of the data
2. Optional timestamp compression for almost-periodic time series
3. Records that meet the needs of the domain
4. Compression technique that suits the domain's data
5. Underlying multi-dimensional storage
6. Domain specific query language with server-side evaluation
7. Domain specific commissioning of configuration parameters

4 beneficial performance effects

- Chronix has a 34% – 69% smaller memory footprint.
- Chronix saves 20% – 68% of the storage space.
- Chronix saves 80% – 92% on data retrieval time.
- Chronix saves 73% – 97% of the runtime of analyzing queries.

www.chronix.io
open source