



A Developer's View Into Spark's Memory Model

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2017-6-7



About Me

- Software Engineer @  databricks®
- Apache Spark Committer
- One of the most active Spark contributors

Jan 27, 2016 – Jun 6, 2017

Contributions: **Commits** ▾

Contributions to master, excluding merge commits



rxin

#1

267 commits / 74,167 ++ / 83,132 --



cloud-fan

#2

238 commits / 20,939 ++ / 19,586 --



About Databricks

TEAM

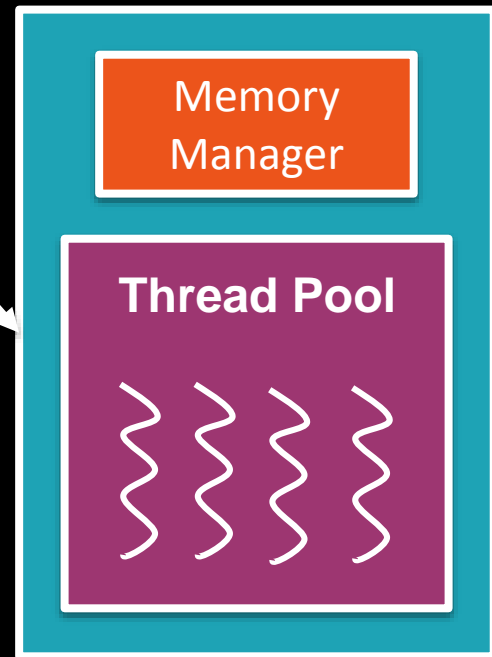
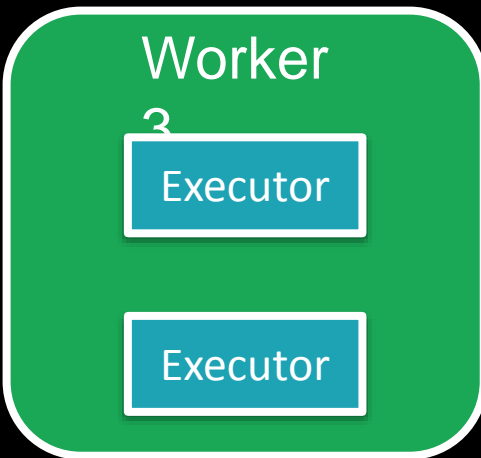
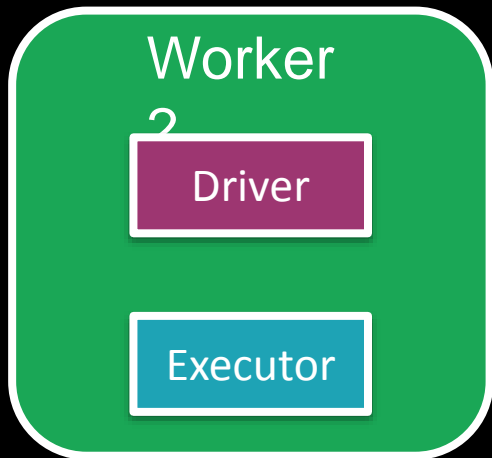
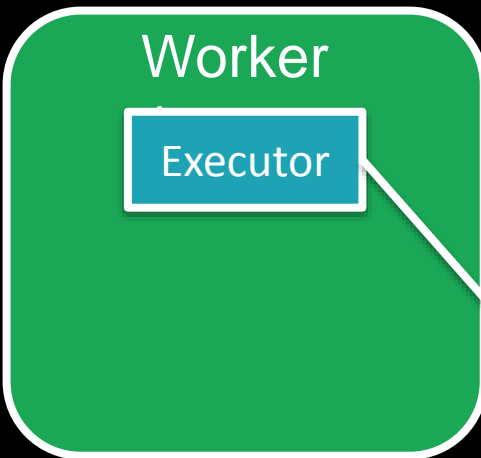
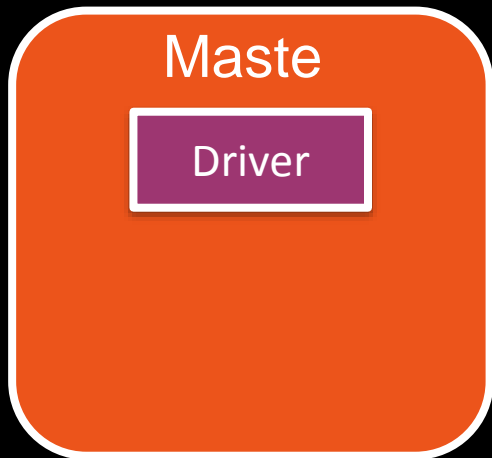
Started Spark project (now Apache Spark) at UC Berkeley in 2009

MISSION

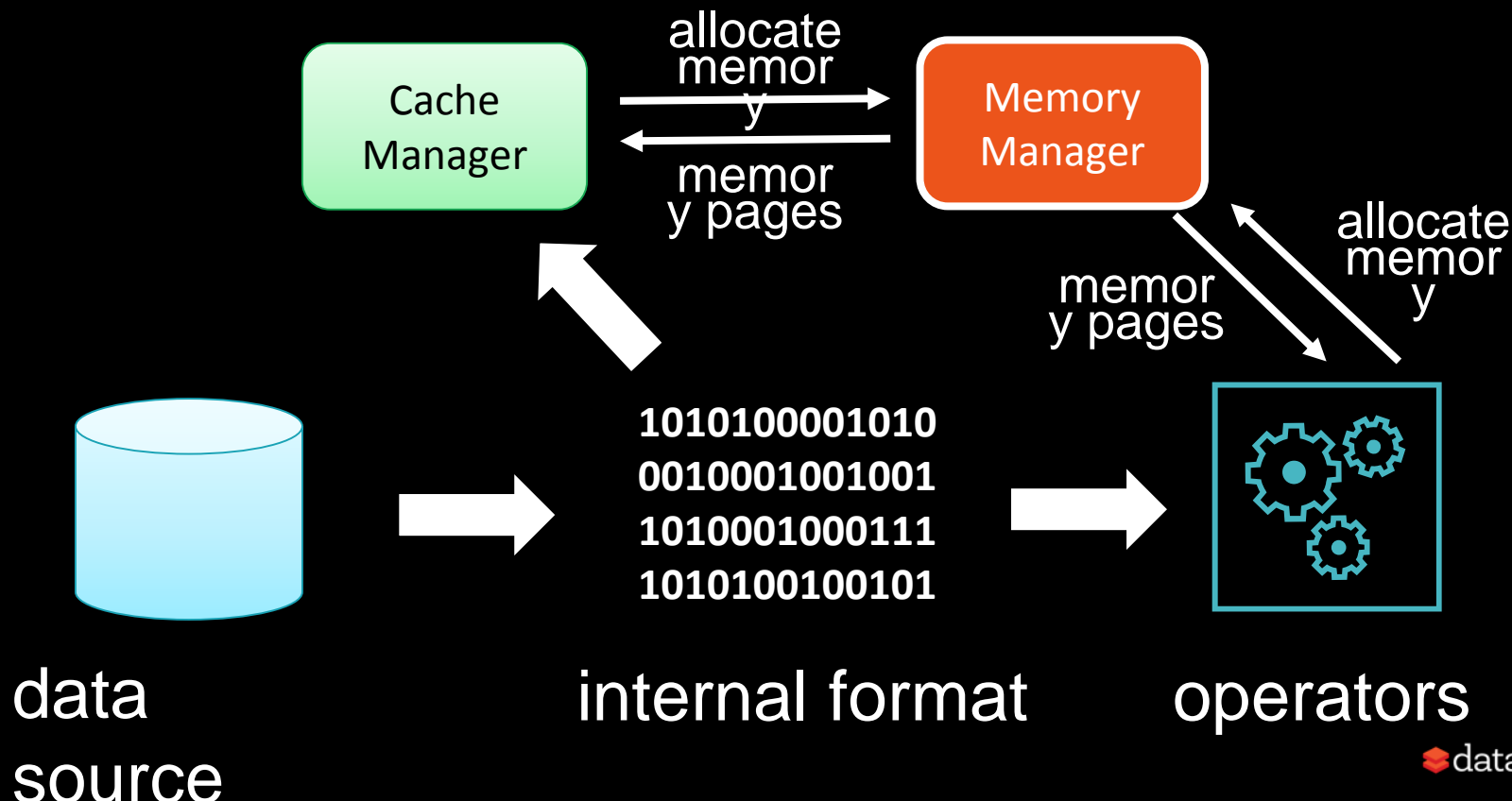
Make Big Data Simple

PRODUCT

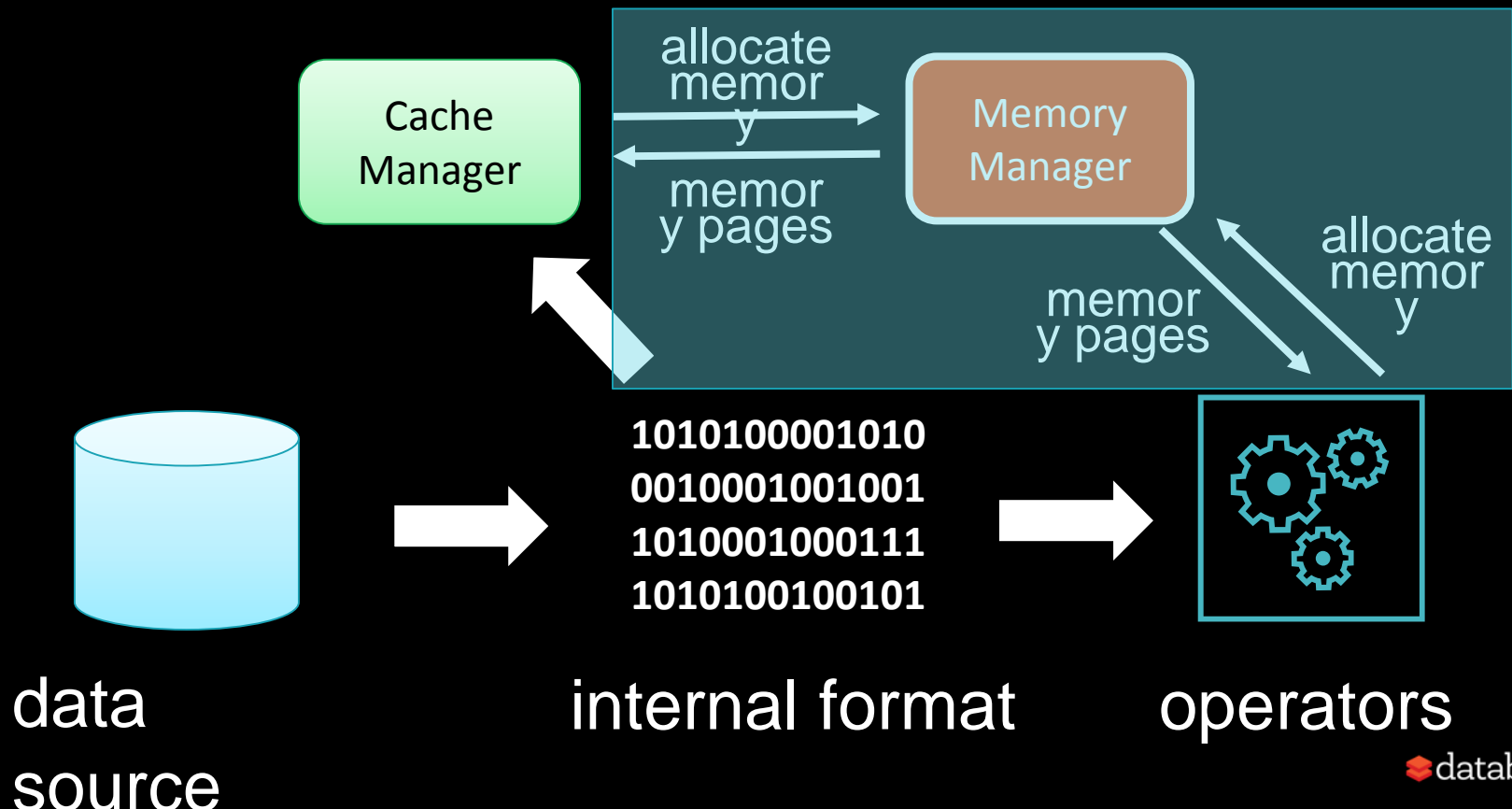
Unified Analytics Platform



Memory Model inside Executor



Memory Model inside Executor



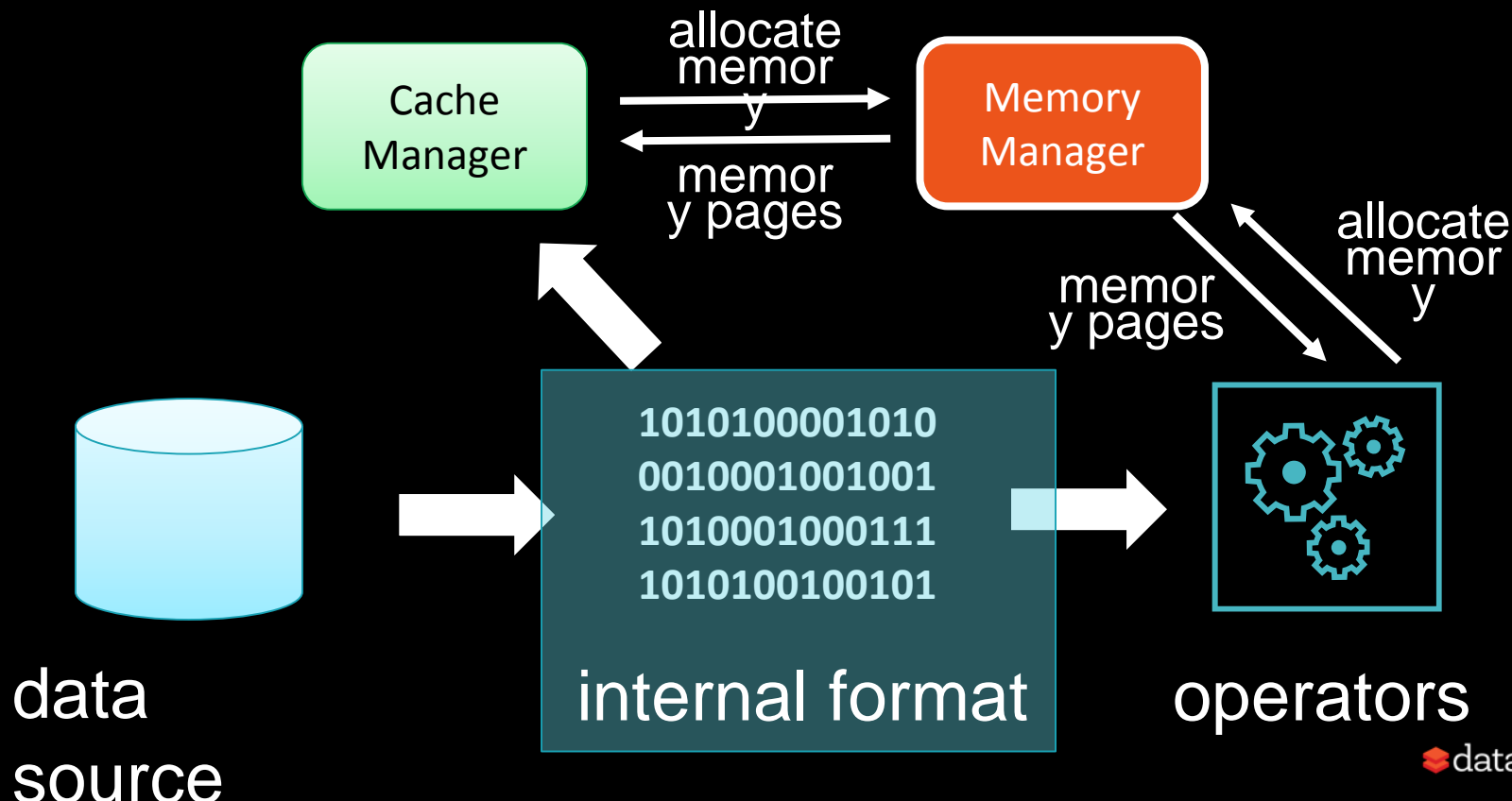
Memory Allocation

- Allocation happens in page granularity.
- Off-heap supported!
- Page is not fixed-size, but has a lower and upper bound.
- No pooling, pages are freed once there is no data on it.

Why var-length page and no pooling?

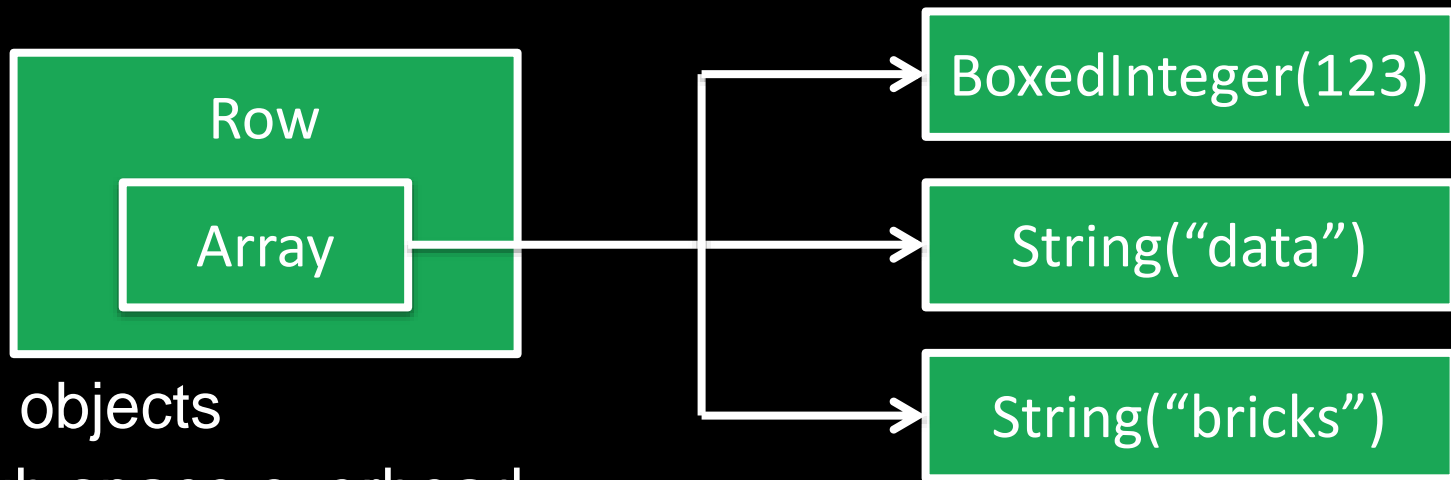
- Pros:
 - simplify the implementation. (no single record will across pages)
 - free memory immediately so that the OS can use them for file buffer, etc.
- Cons:
 - can not handle super big single record. (very rare in reality)
 - fragmentation for records bigger than page size lower bound. (the lower bound is several mega bytes, so it's also rare)
 - overhead in allocation. (most malloc algorithms should work well)

Memory Model inside Executor



Java Objects Based Row Format

(123, "data", "bricks")



- 5+ objects
- high space overhead
- slow value accessing
- expensive hashCode()

Data objects? No!

- It is hard to monitor and control the memory usage when we have a lot of objects.
- Garbage collection will be the killer.
- High serialization cost when transfer data inside cluster.

Efficient Binary Format

(123, "data", "bricks")



null tracking

Efficient Binary Format

(123, "data", "bricks")



0x0

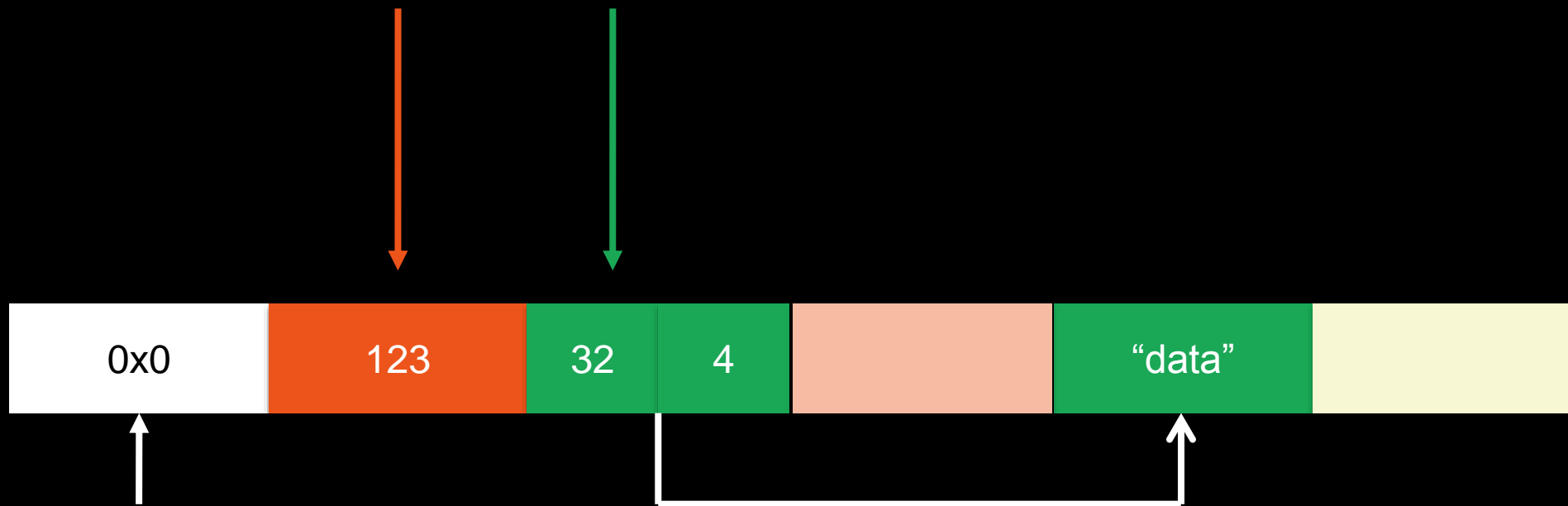
123



null tracking

Efficient Binary Format

(123, "data", "bricks")

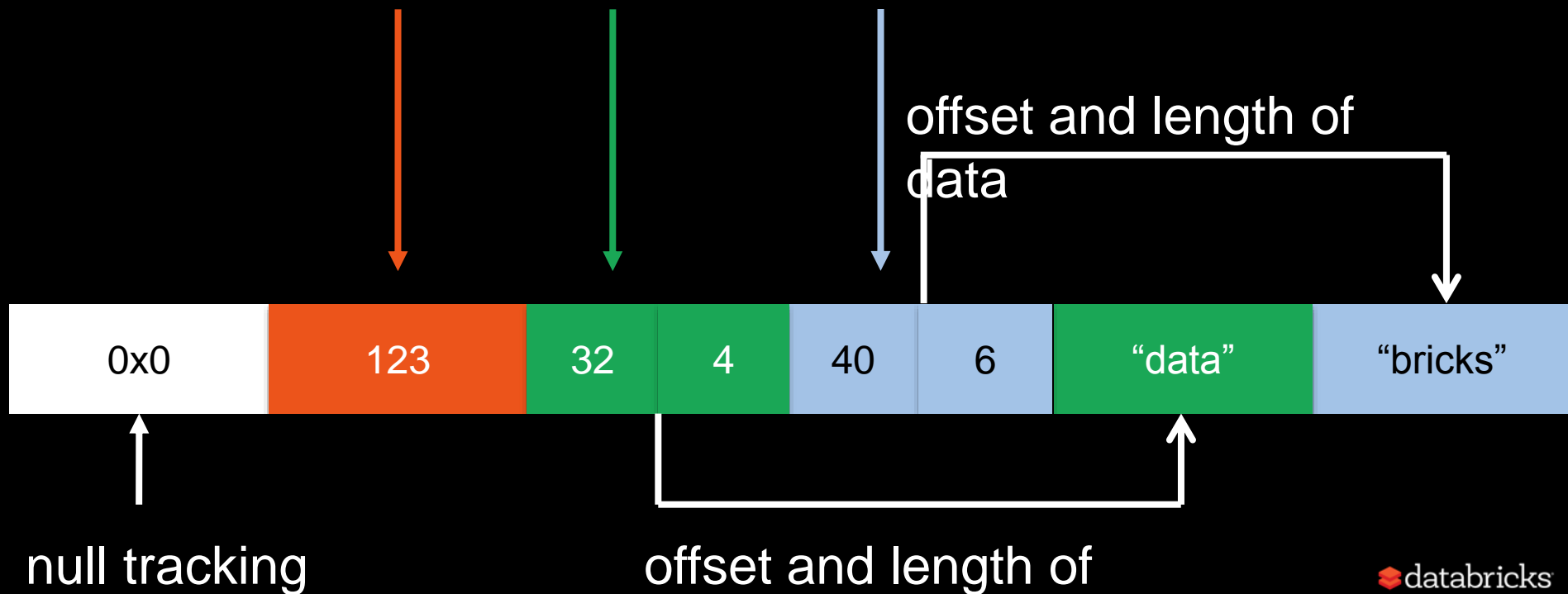


null tracking

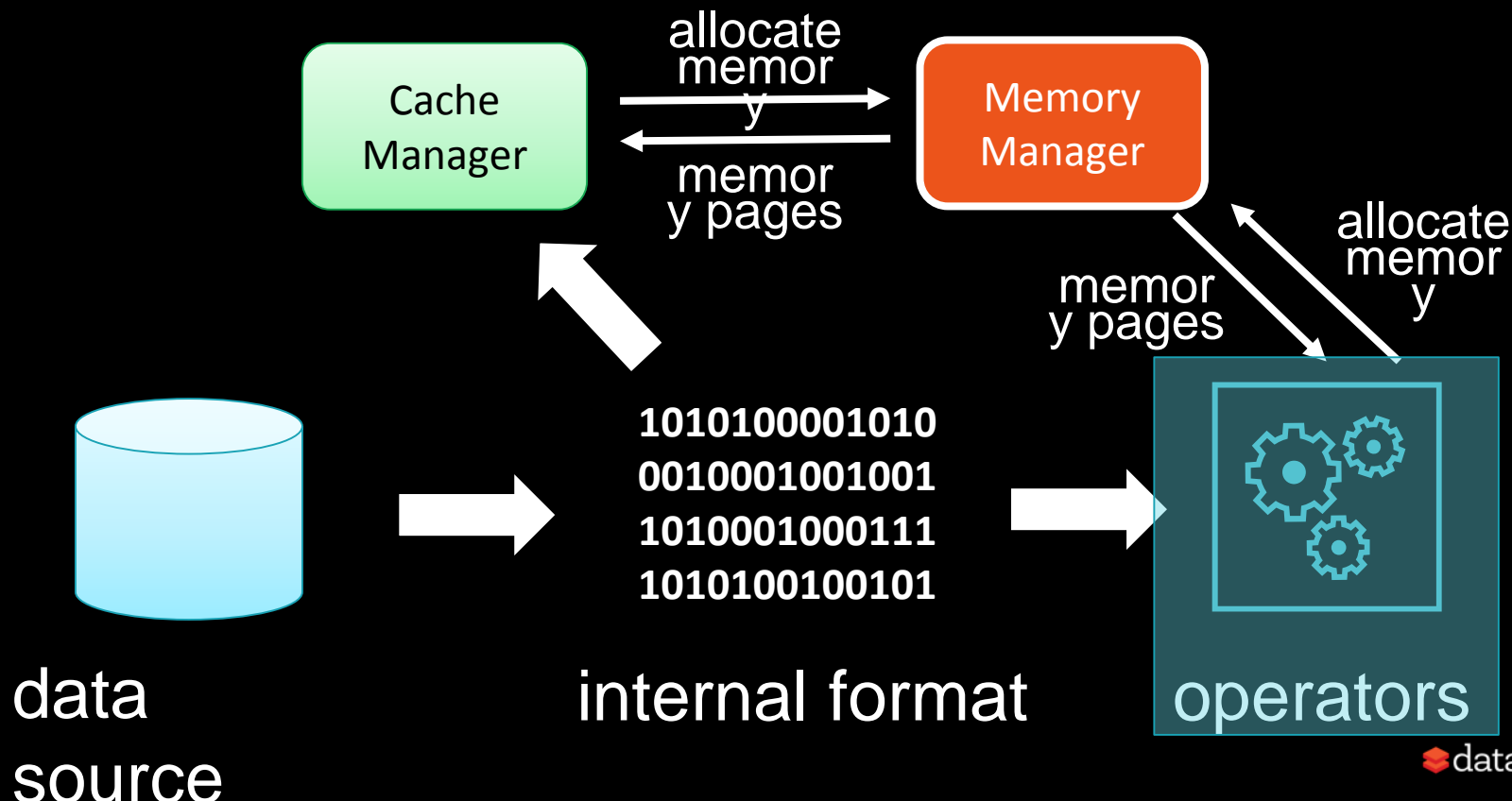
offset and length of

Efficient Binary Format

(123, "data", "bricks")

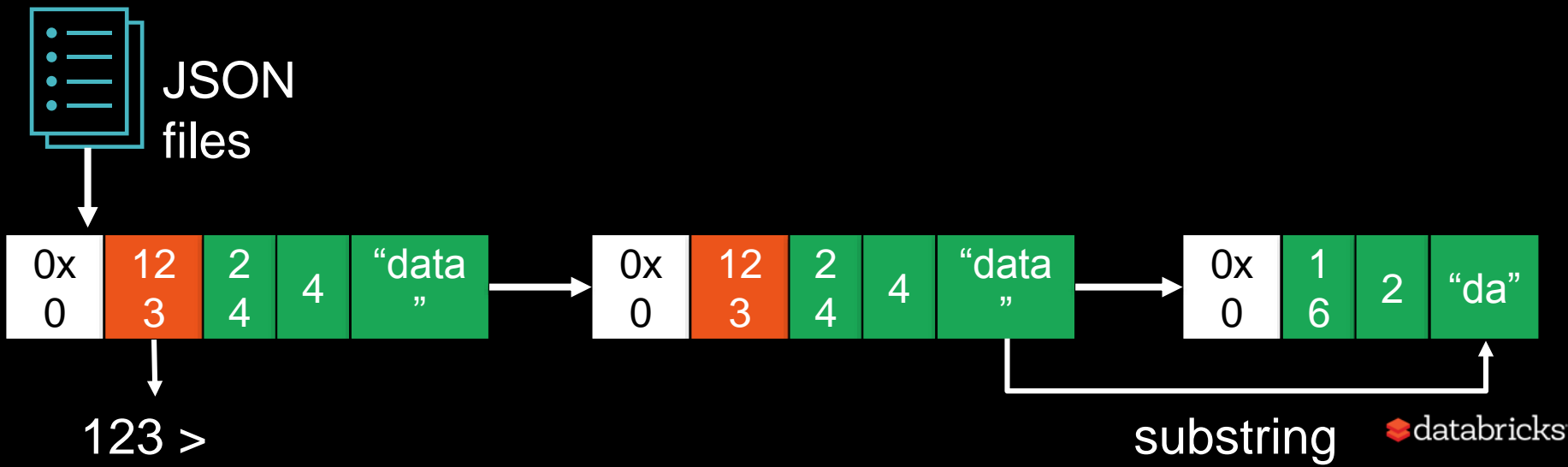


Memory Model inside Executor



Operate On Binary

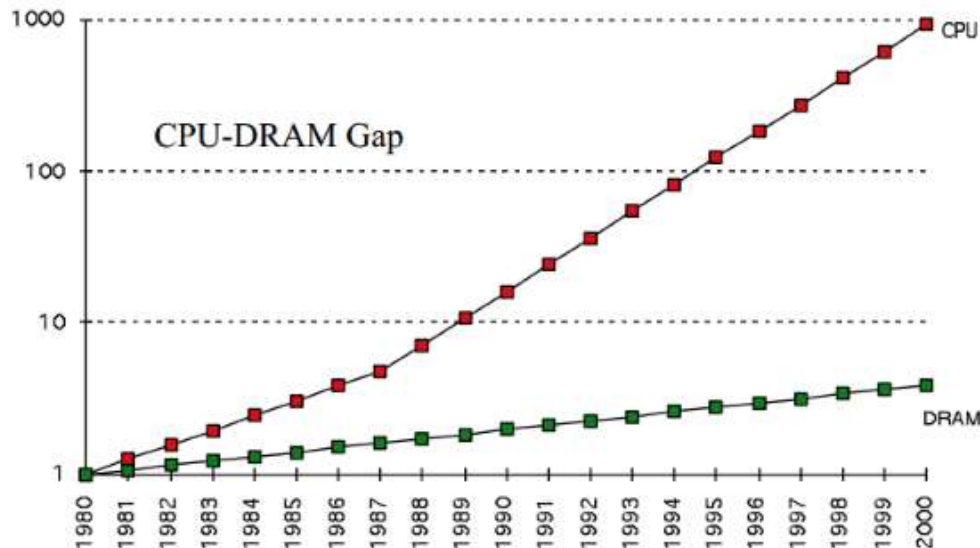
```
spark.read.schema("i int, j string").json("/tmp/x.json")  
  .filter($"i" > 0)  
  .select($"j".substr(0, 2))
```



How to process binary data more efficiently?

Understanding CPU Cache

■ Processor vs Memory Performance

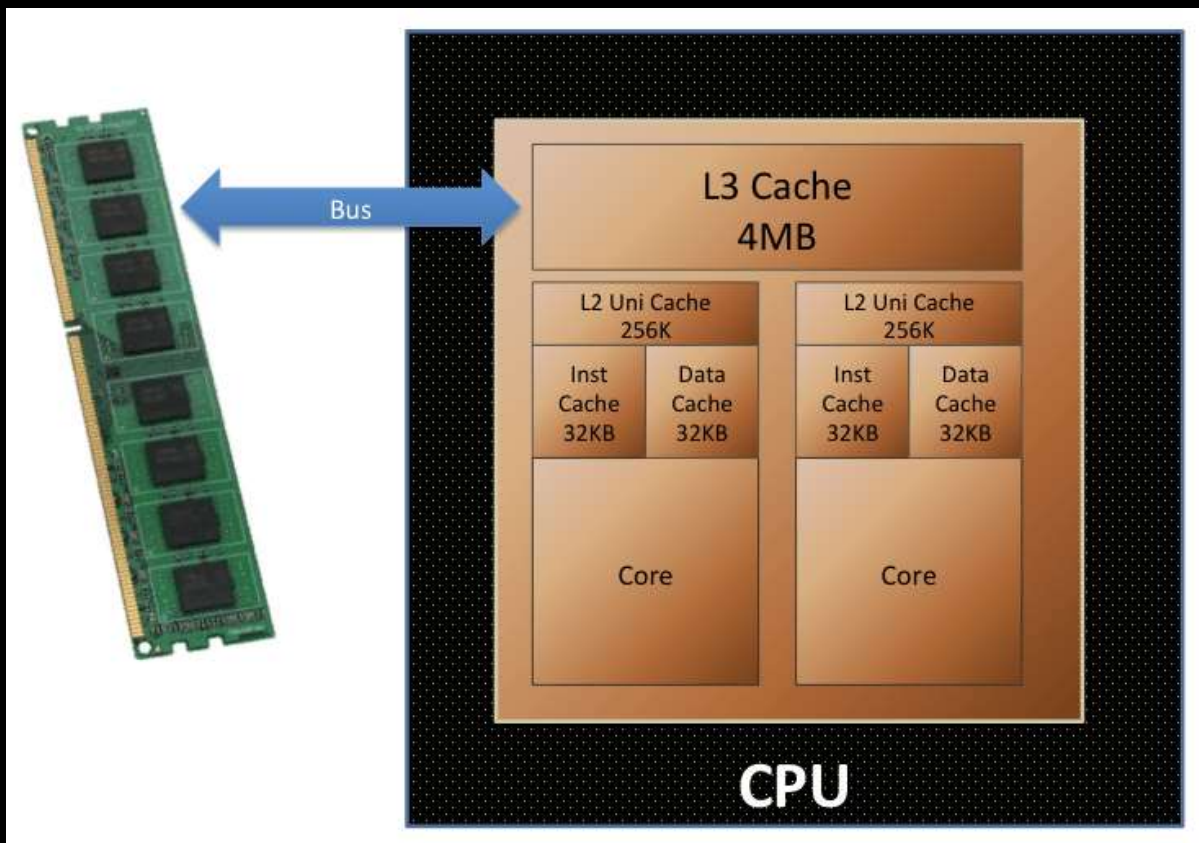


1980: no cache in microprocessor;

1995 2-level cache

Memory is becoming slower and slower than CPU.

Understanding CPU Cache

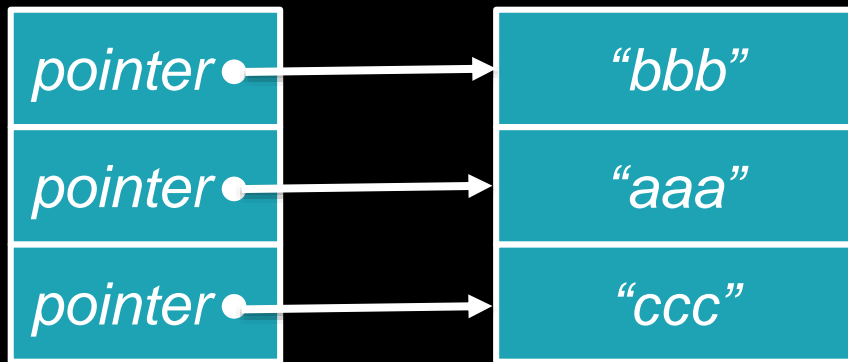


Pre-fetch frequently accessed data into CPU cache.

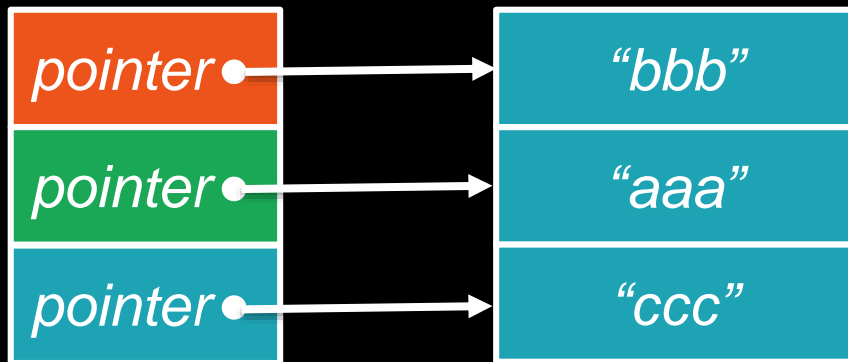
The most 2 important
algorithms in big data
are ...

Sort and Hash!

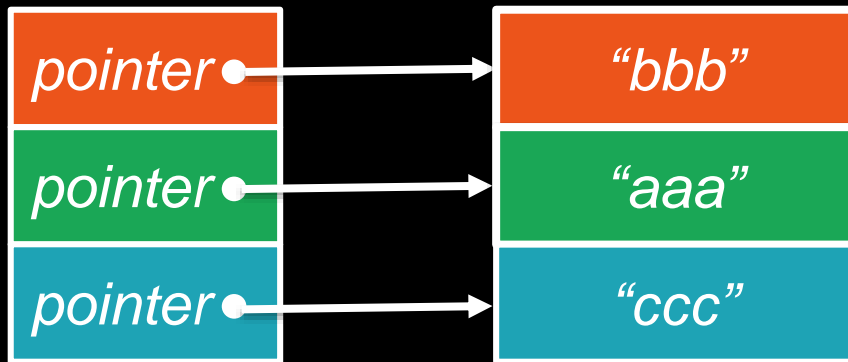
Naive Sort



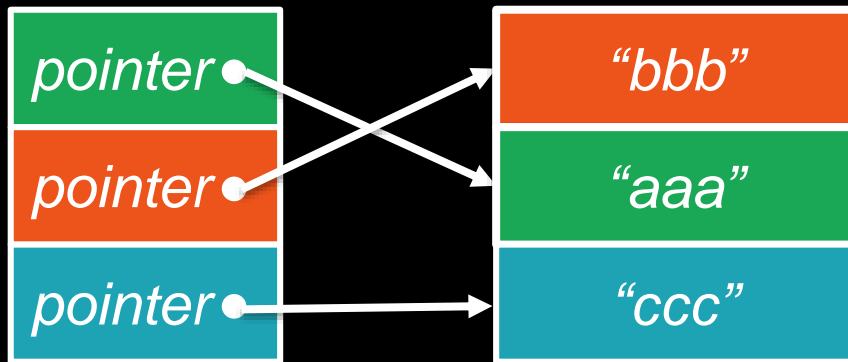
Naive Sort



Naive Sort



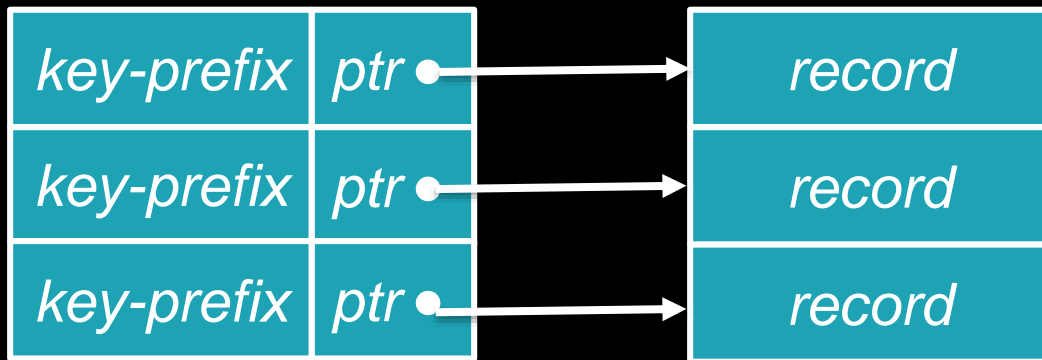
Naive Sort



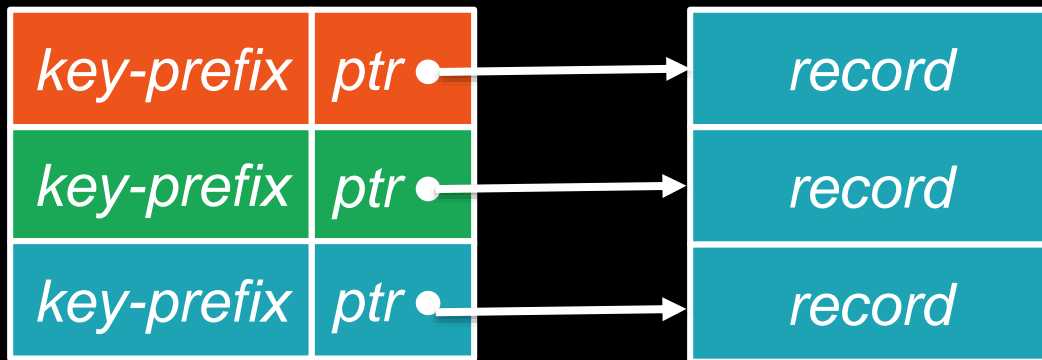
Naive Sort

Each comparison needs to access 2 different memory regions, which makes it hard for CPU cache to pre-fetch data, poor cache locality!

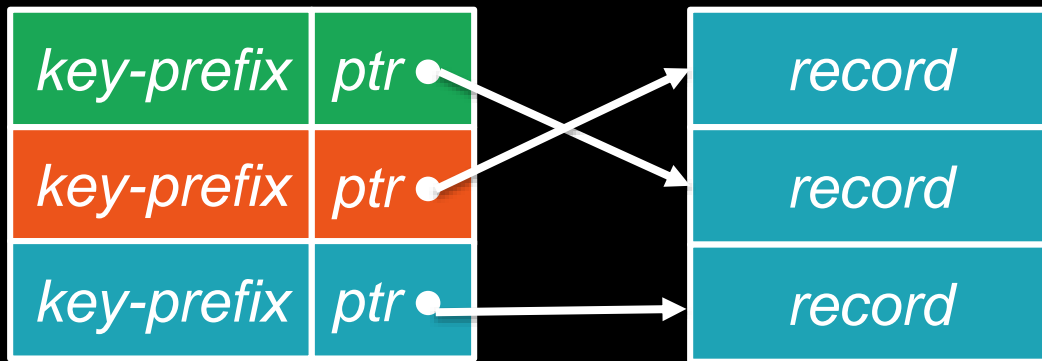
Cache-aware Sort



Cache-aware Sort



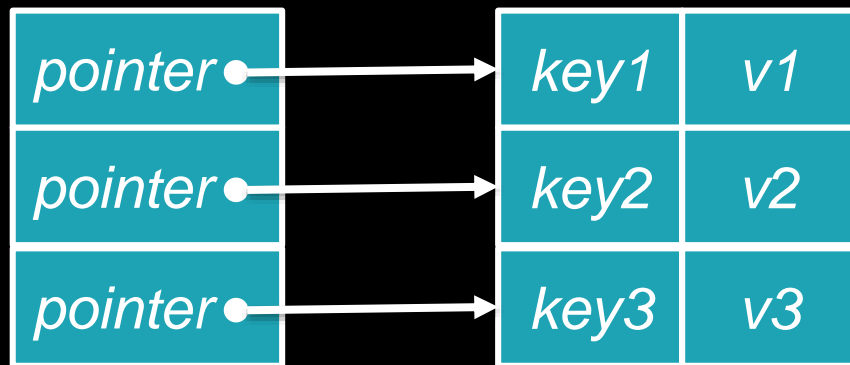
Cache-aware Sort



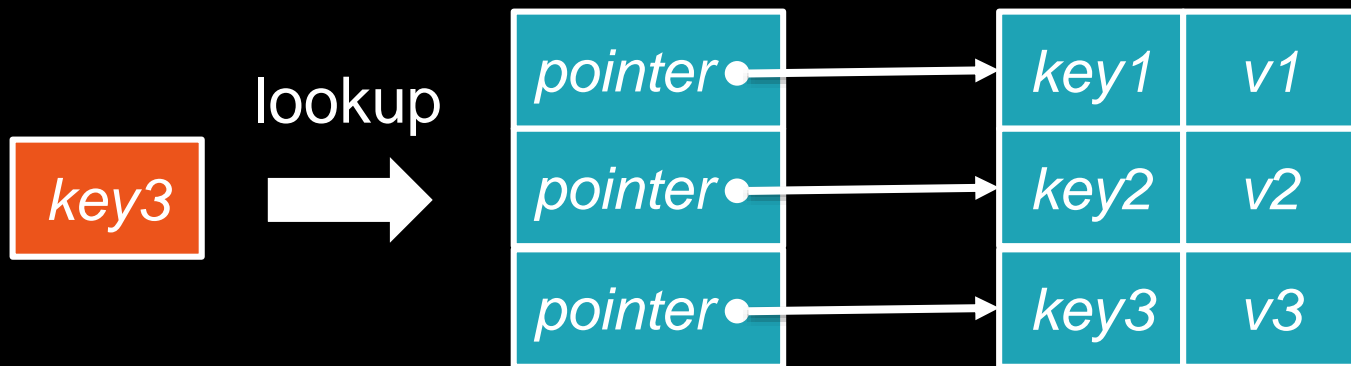
Cache-aware Sort

Most of the time, just go through the key-prefixes in a linear fashion, good cache locality!

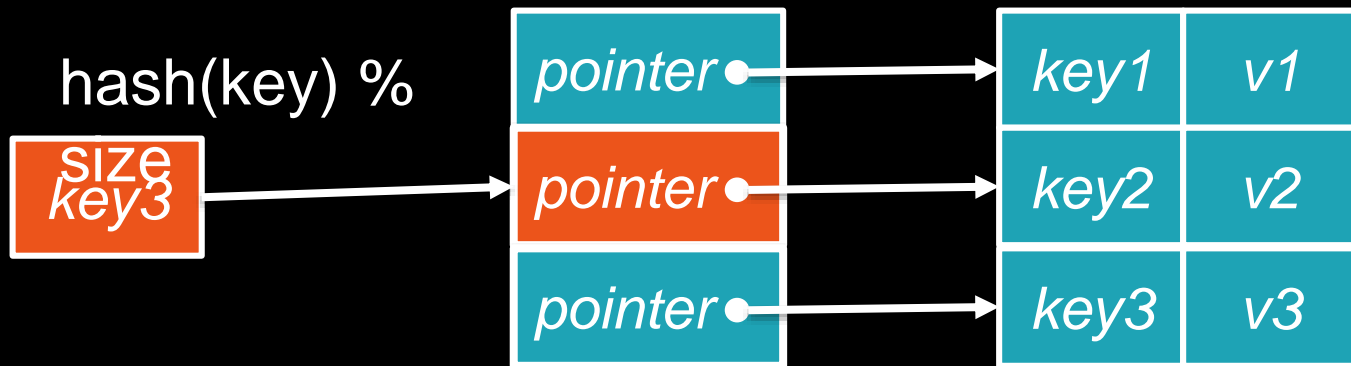
Naive Hash Map



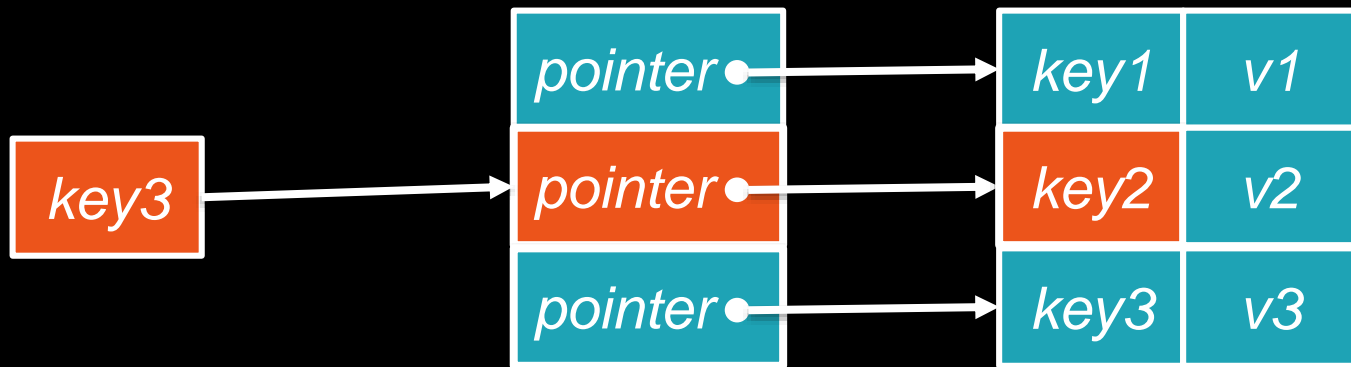
Naive Hash Map



Naive Hash Map

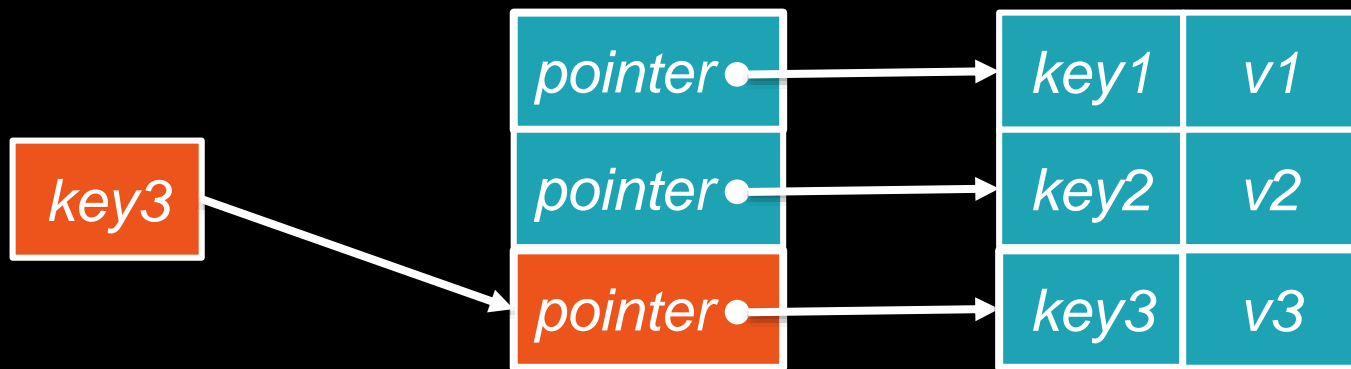


Naive Hash Map



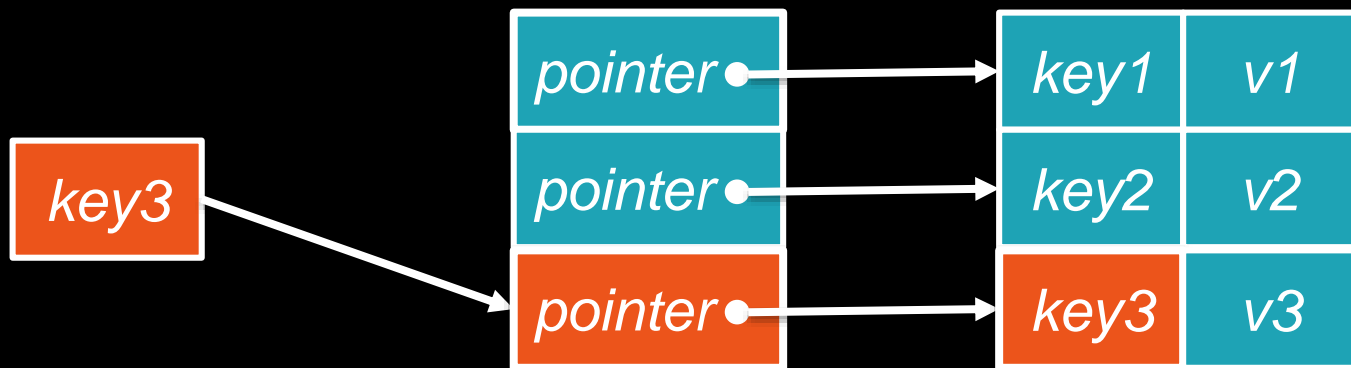
compare these 2
keys

Naive Hash Map



quadratic
probing

Naive Hash Map

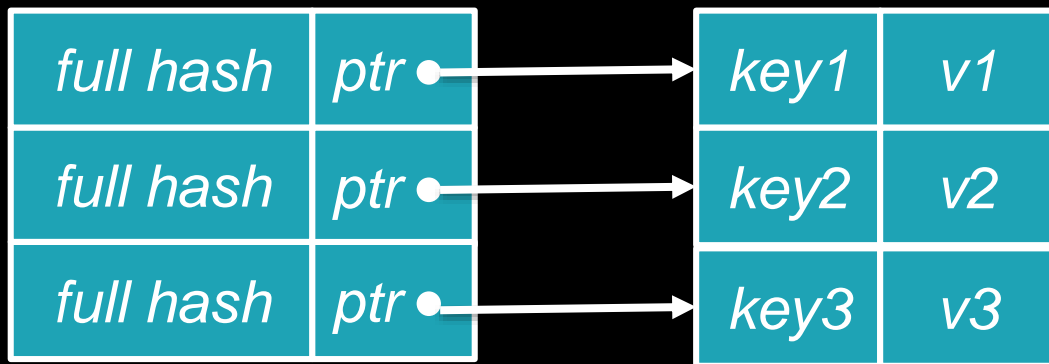


compare these 2
keys

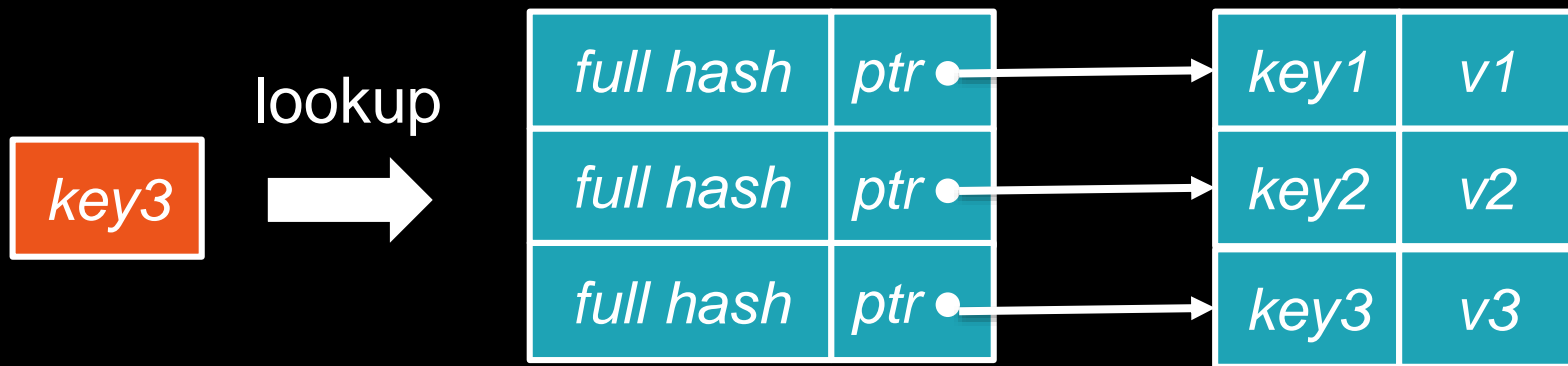
Naive Hash Map

Each lookup needs many pointer dereferences and key comparison when hash collision happens, and jumps between 2 memory regions, bad cache locality!

Cache-aware Hash Map



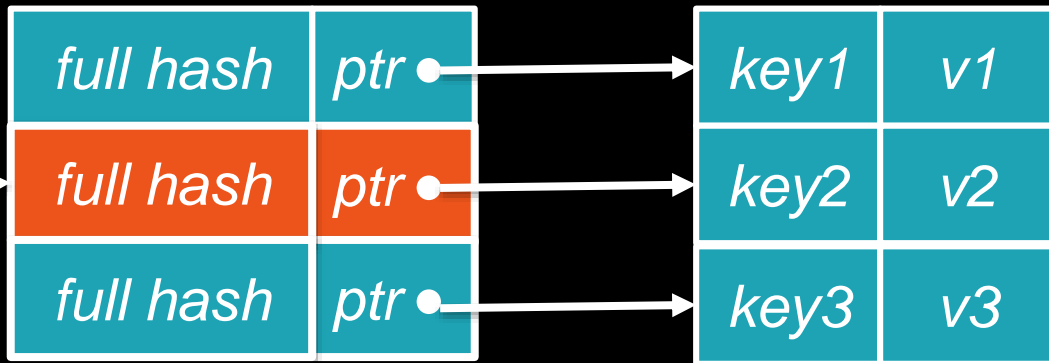
Cache-aware Hash Map



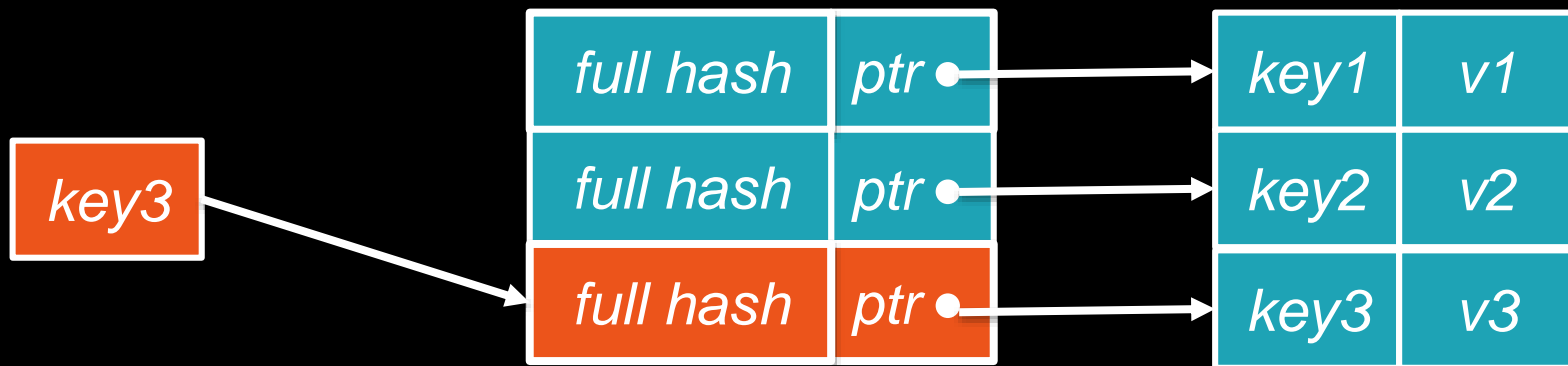
Cache-aware Hash Map

hash(key) %
size, and
compare the full

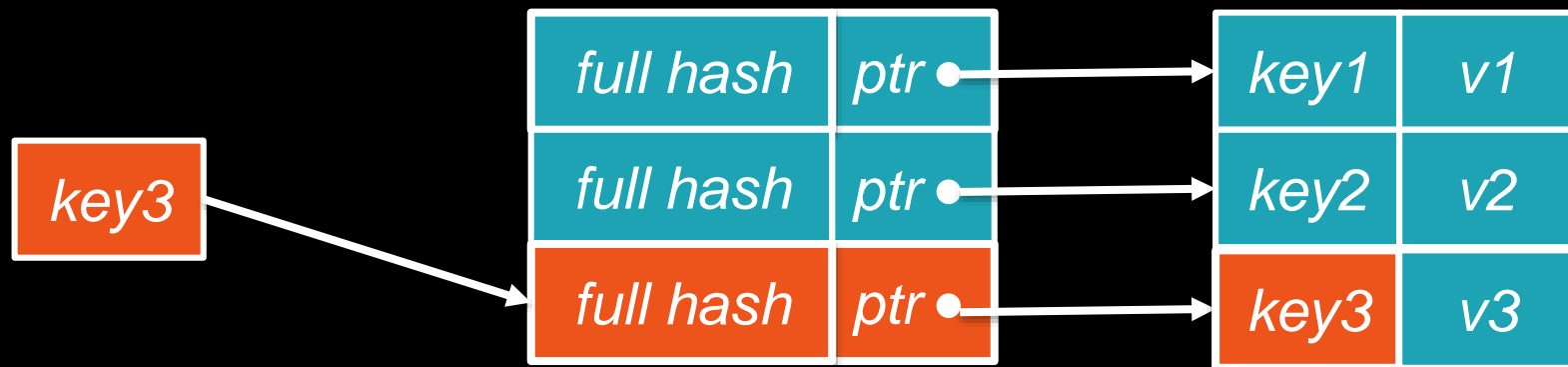
hash
key3



Cache-aware Hash Map



Cache-aware Hash Map



compare these 2
keys

Cache-aware Hash Map

Each lookup mostly only needs one pointer dereference and key comparison (full hash collision is rare), and access data mostly in a single memory region, better cache locality!

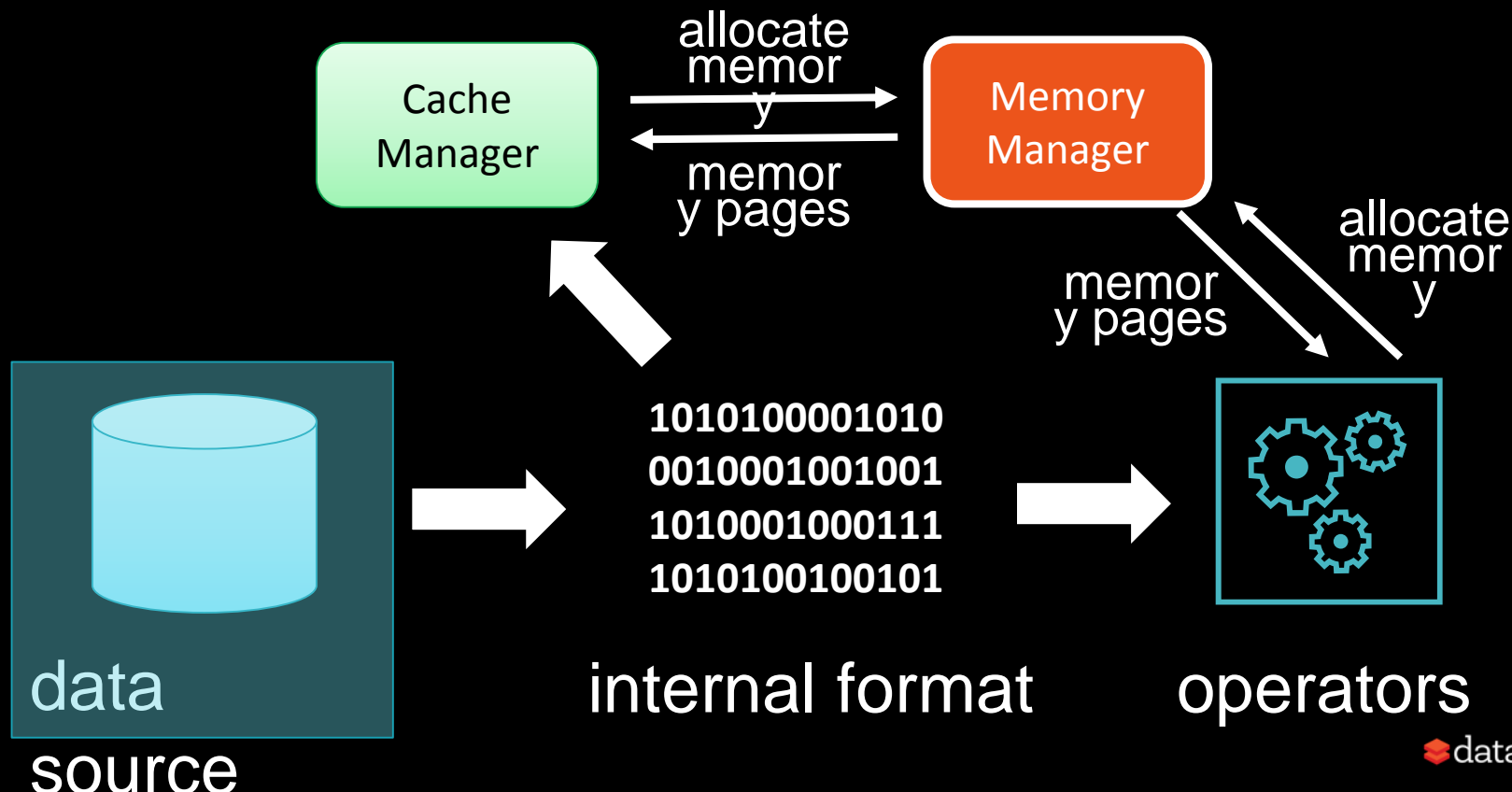
Recap: Cache-aware data structure

How to improve cache locality ...

- store key-prefix with pointer.
- store key full hash with pointer.

Store extra information to try to keep the memory accessing in a single region.

Memory Model inside Executor



Future Work

- SPARK-19489: Stable serialization format for external & native code integration.
- SPARK-15689: Data source API v2
- SPARK-15687: Columnar execution engine.

Try Apache Spark in Databricks!

UNIFIED ANALYTICS PLATFORM

- Collaborative cloud environment
- Free version (community edition)

DATABRICKS RUNTIME

3.0

- Apache Spark - optimized for the cloud
- Caching and optimization layer - DBIO
- Enterprise security - DBES

Try for free
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The background features a dark, textured surface with vibrant, abstract brushstrokes in shades of red, orange, and teal. A series of light gray, three-dimensional diamond shapes are arranged in a grid-like pattern, receding into the distance.

Thank You