Sortedness-Aware Indexing

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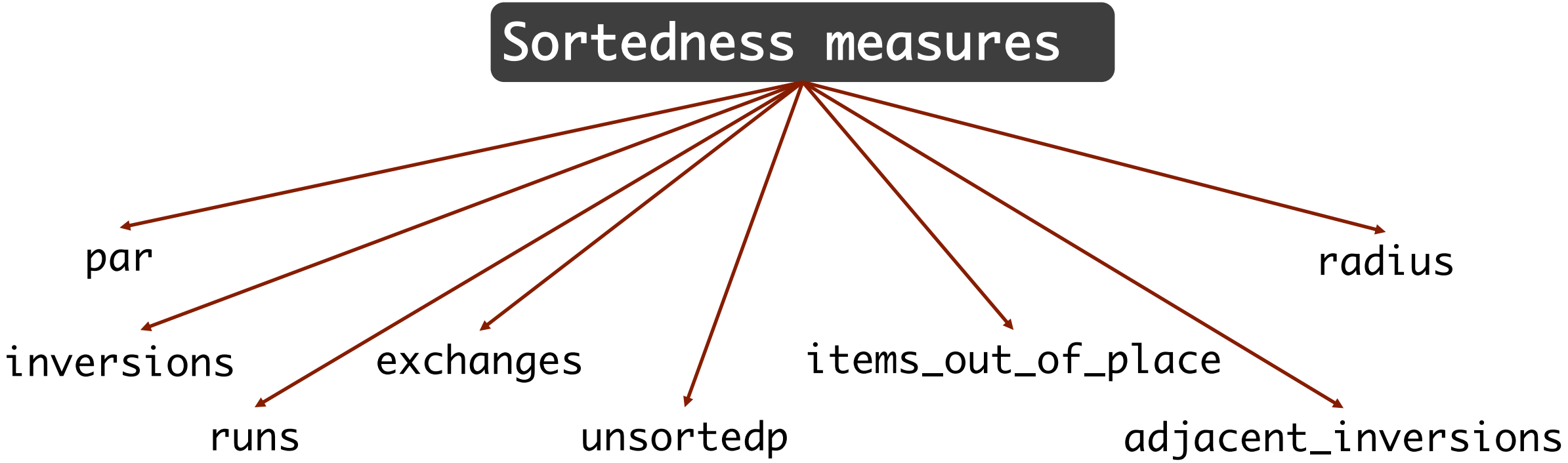
DiSC lab

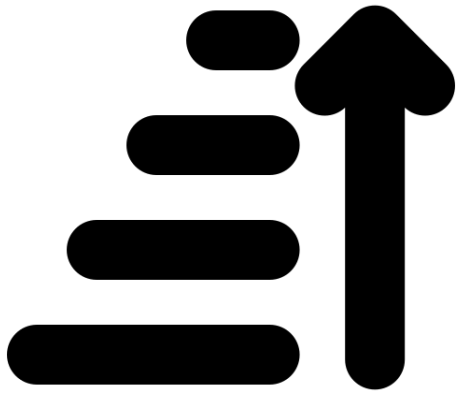
Sortedness

Refers to the ***structure*** or ***order*** in data

Quantifying Sortedness



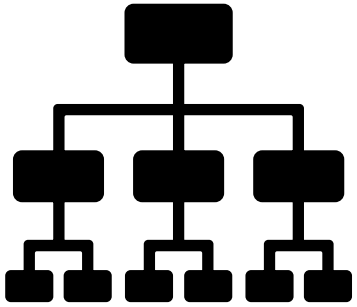
Research Focus



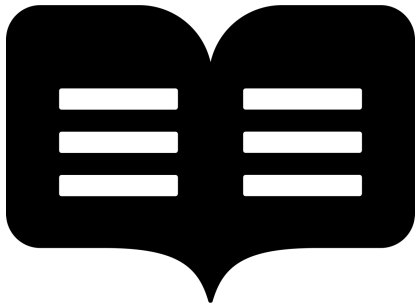
sorting algos. have
adapted to pre-sortedness

can other components of a
data system exploit
intrinsic data ordering?

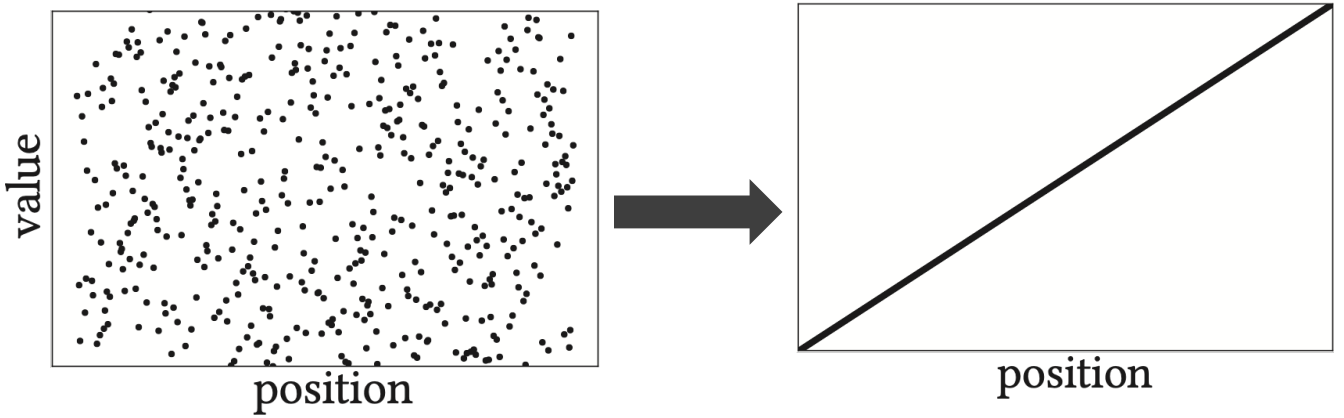
Indexes in Databases



organize data



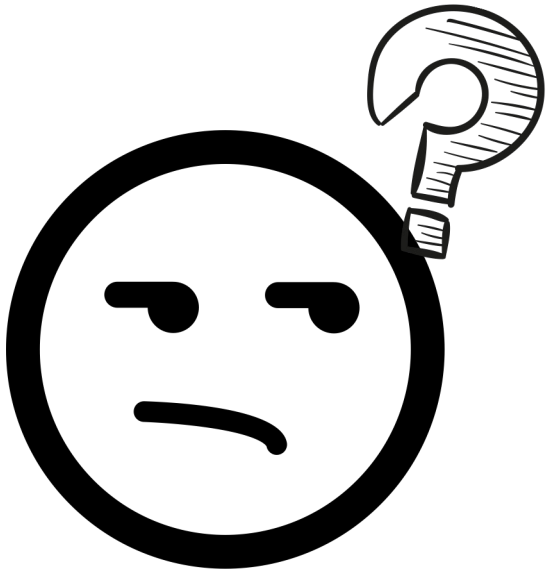
efficient queries



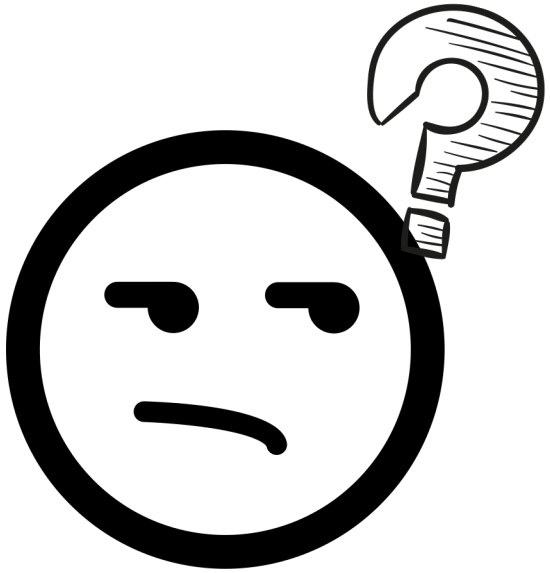
unstructured data

structured data

The process of inducing "*sortedness*" to an otherwise unsorted data collection



What if we already have some structure?



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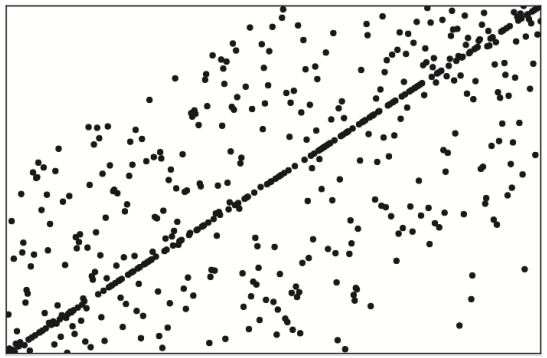
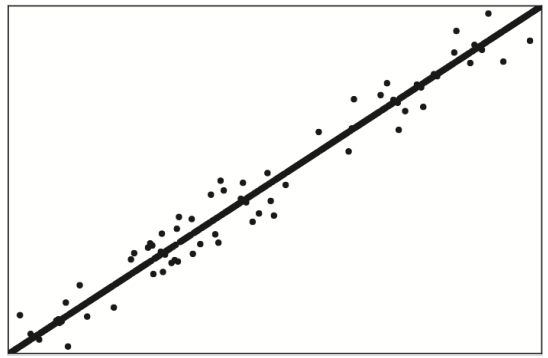
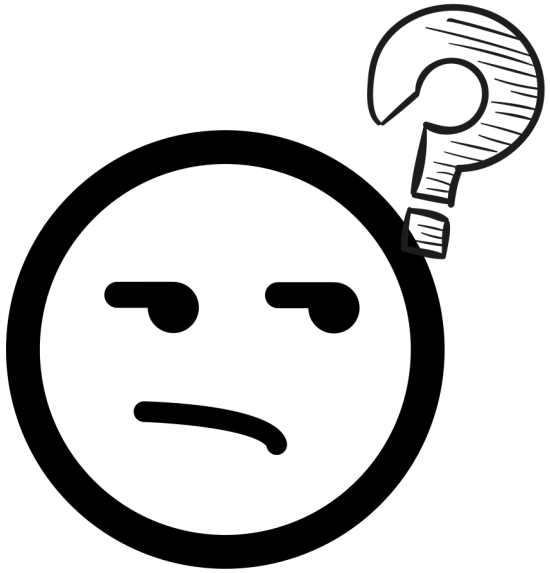




Near-sorted data



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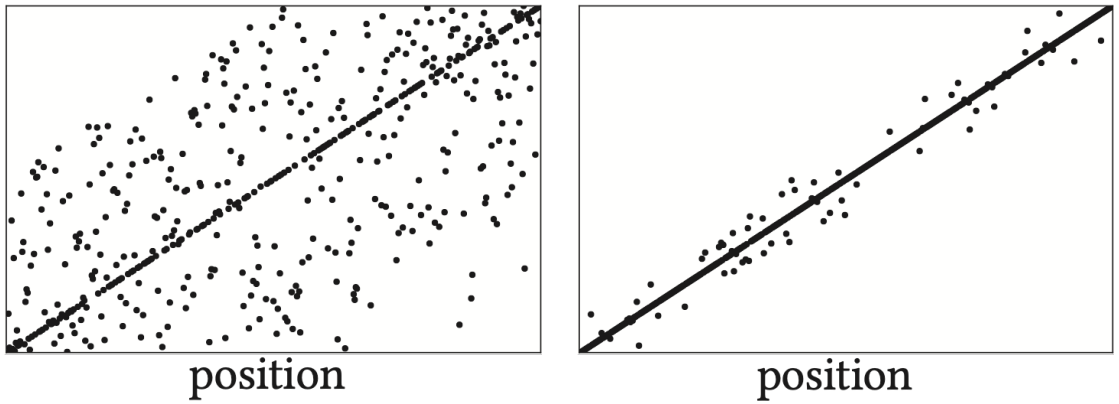
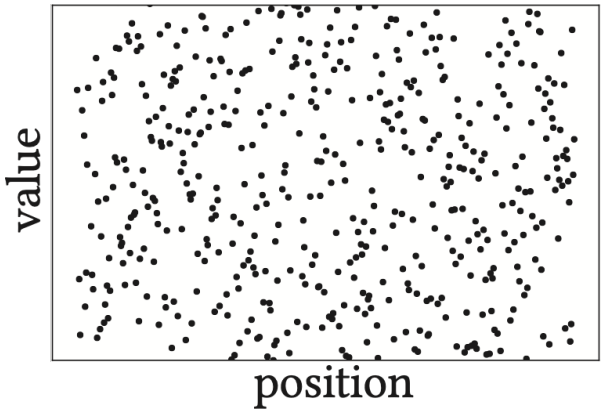


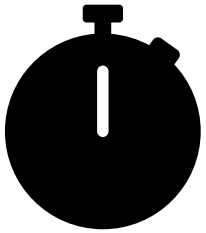
Near-sorted data

$\approx$



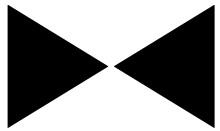
treated same as unstructured data!

Intermediate-Sortedness in Practice

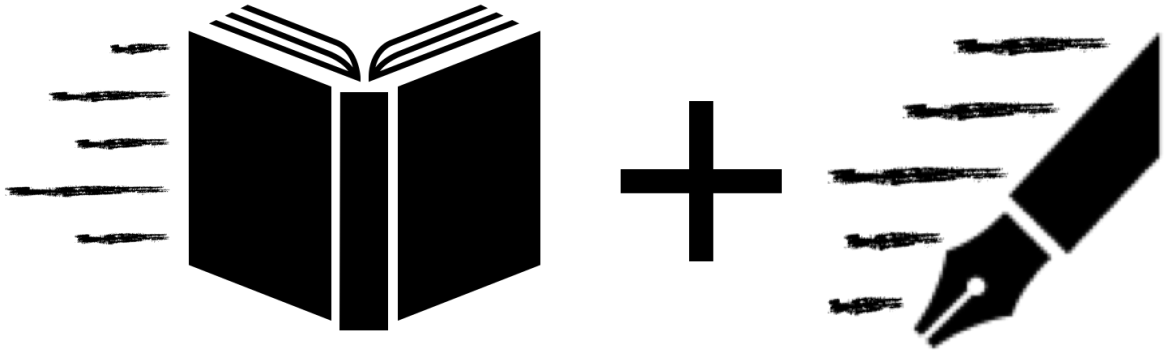


Time Series

Stock market



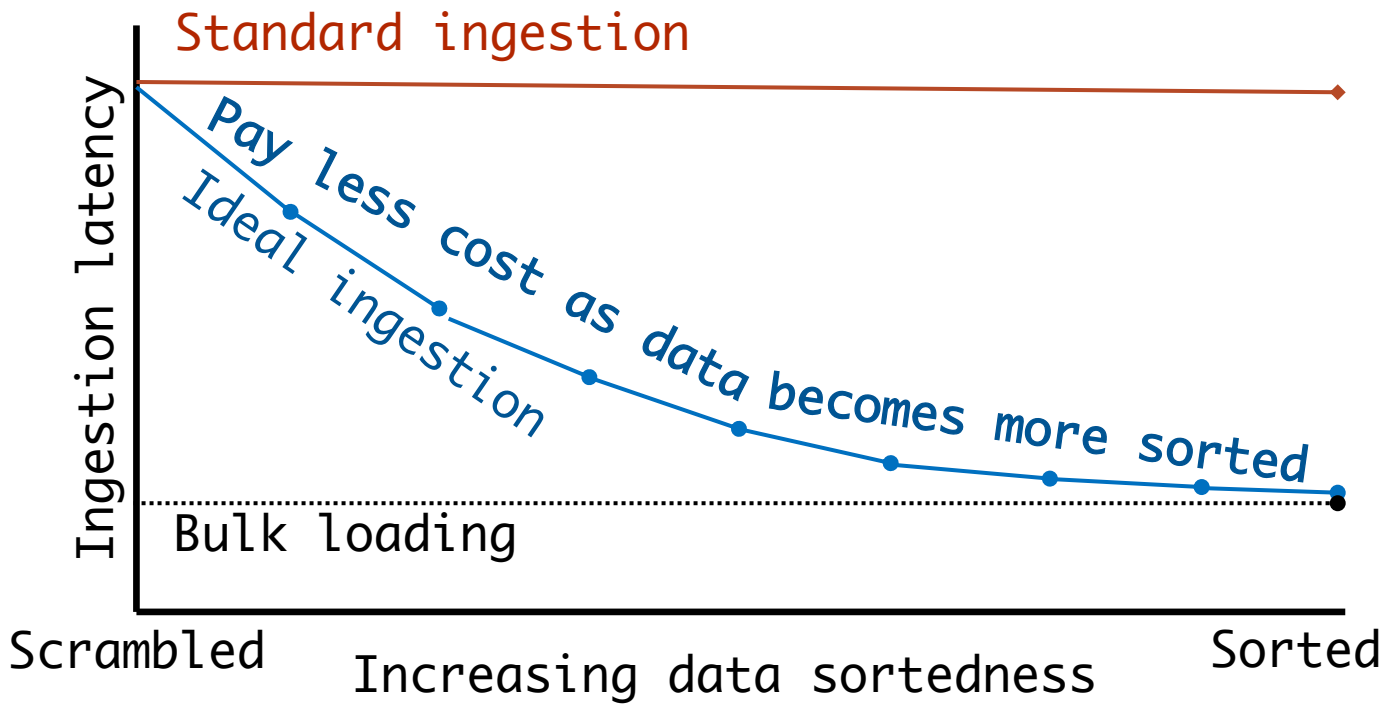
Join/query



efficient reads + fast writes

classical indexes carry *redundant* effort!

In an Ideal Tree...



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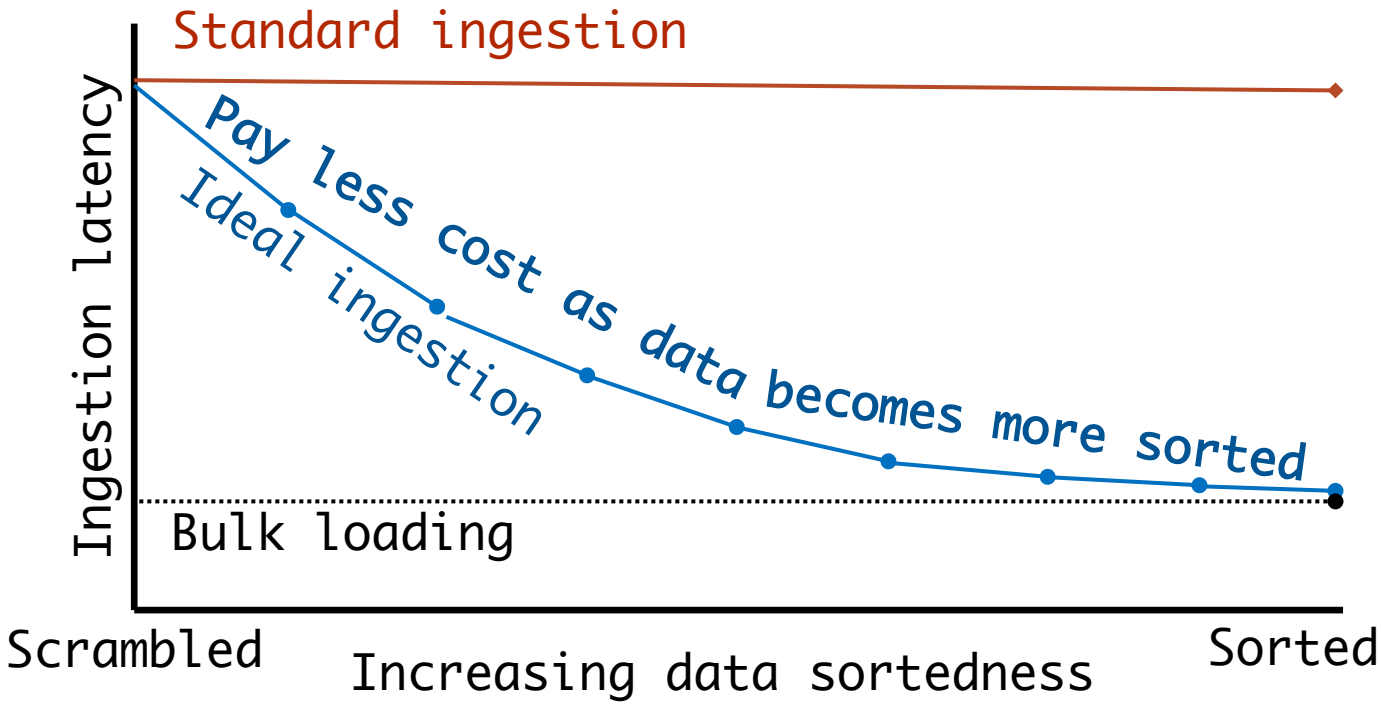

Is this possible?

1. Unexplored study with sortedness
2. Lack of testing framework
3. No such existing index design

The Benchmark on Data Sortedness (BoDS)

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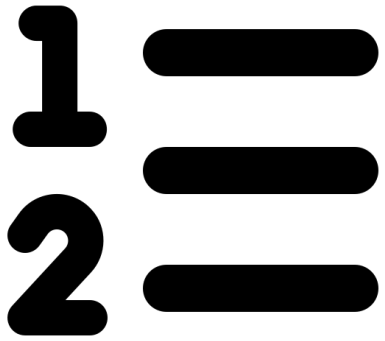

Variable Sortedness
Data Generator

+

Benchmarking
Suite

Quantifying Data Sortedness

Metric	Description
Inversions	# pairs in incorrect order
Runs	# increasing contiguous subsequences
Exchanges	least # swaps needed to establish total order

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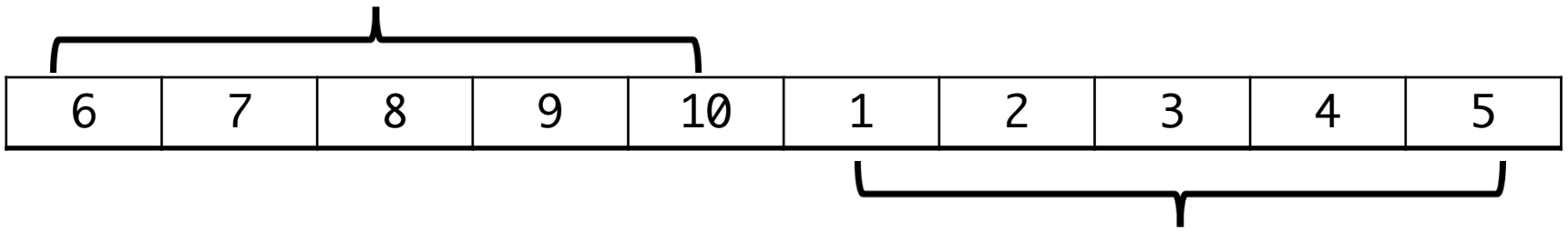

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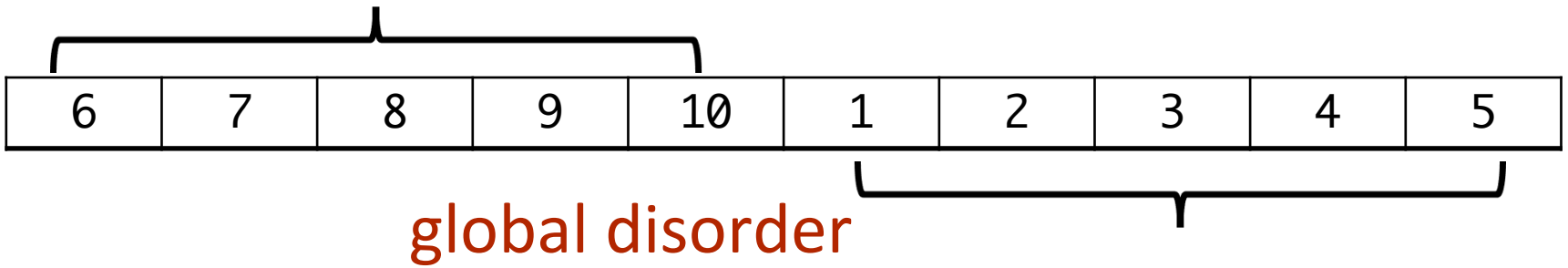

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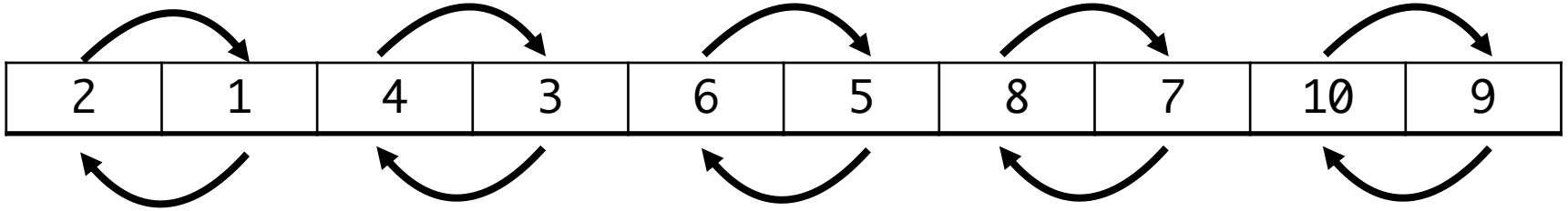

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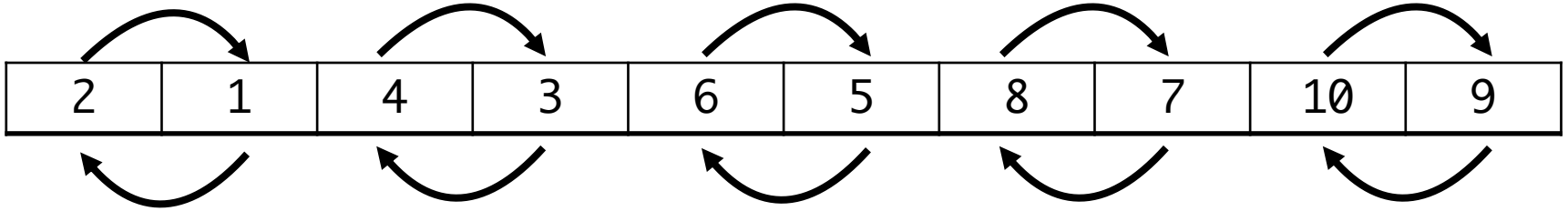
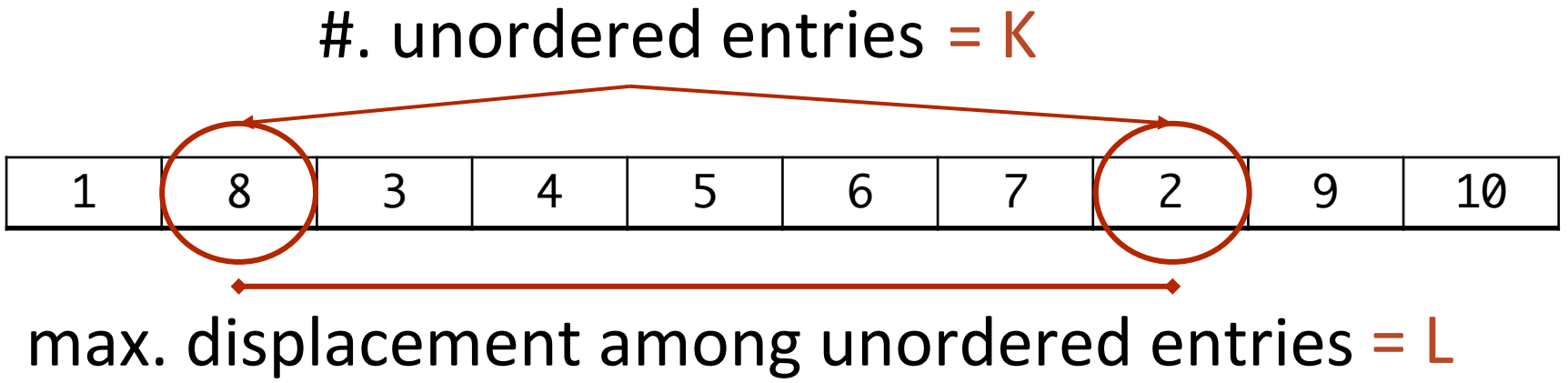


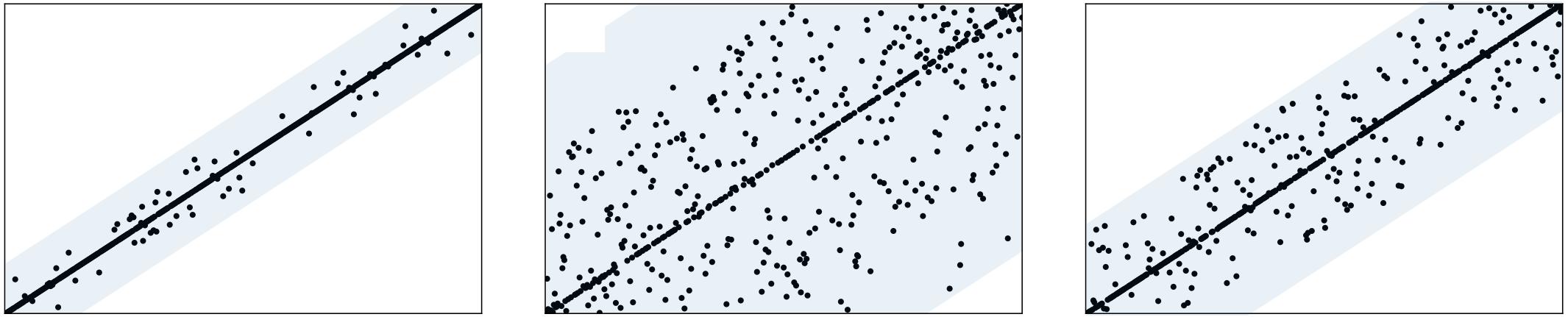
local disorder

(K, L)-Sortedness Metric

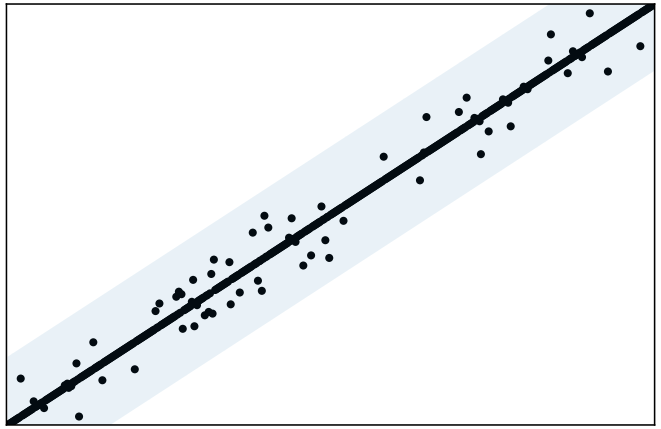


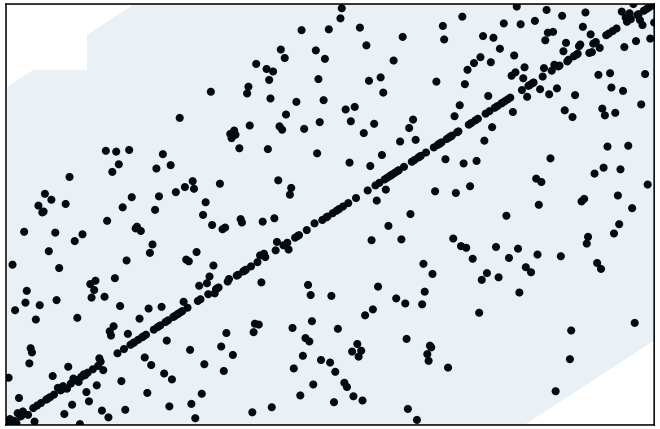
[BenMoshe, ICDT 2011]

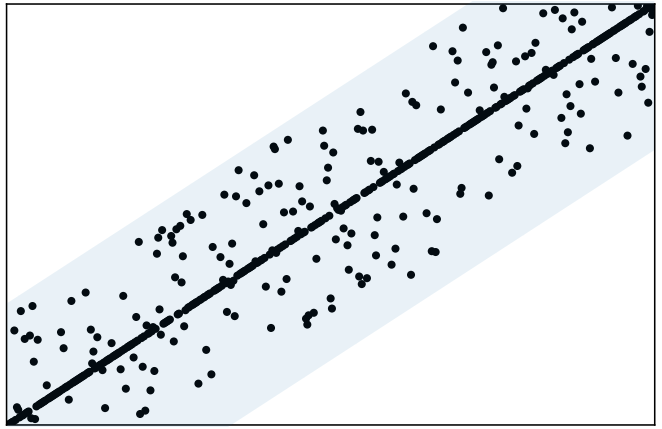
Differently Sorted Data

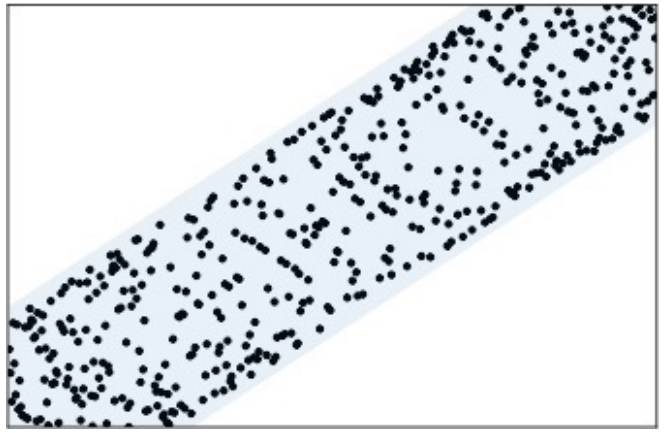


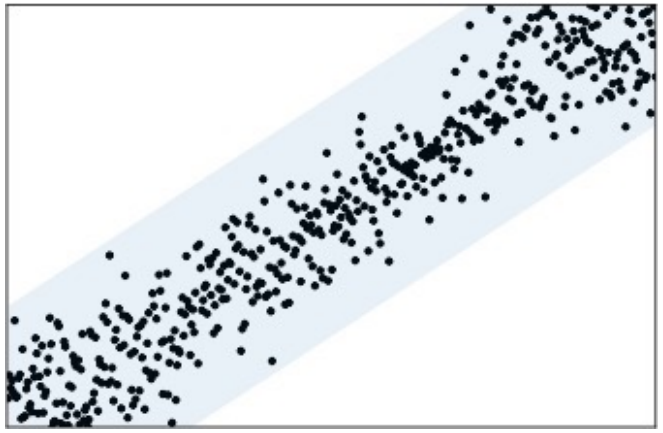
Is (K,L) Enough?











What if we want to distribute the unordered entries differently?

Displacement (L) Distribution

$B(\alpha, \beta)$ **bounded between** $[-L, L]$

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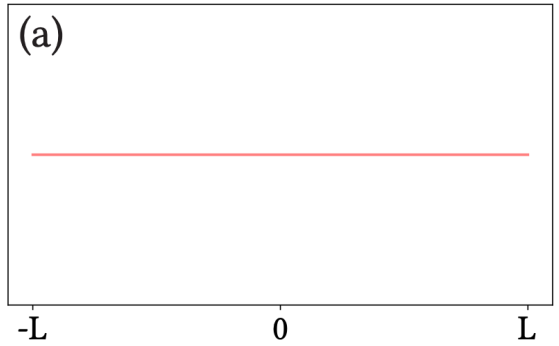

$\alpha = \beta = 1$

Displacement (L) Distribution

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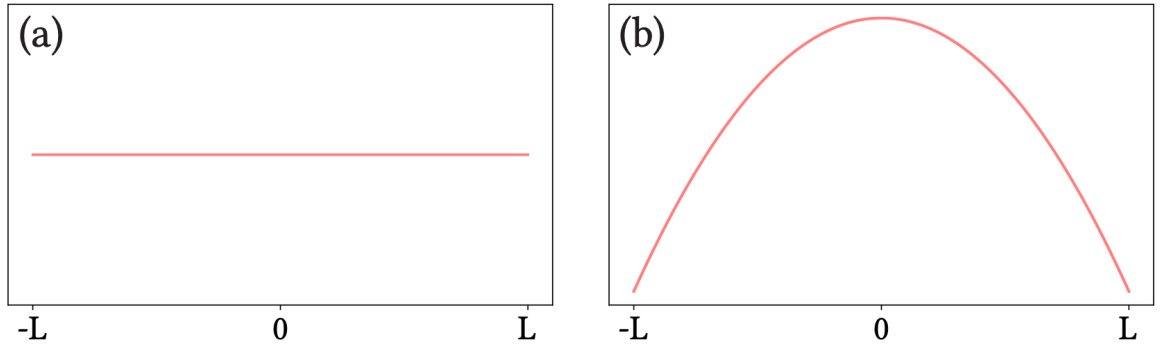

$\alpha = \beta = 1$ $\alpha = \beta = 2$

Displacement (L) Distribution

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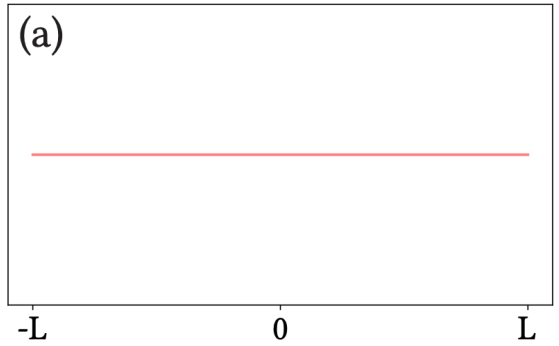

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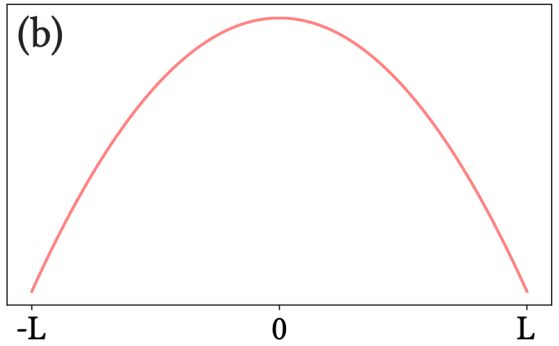
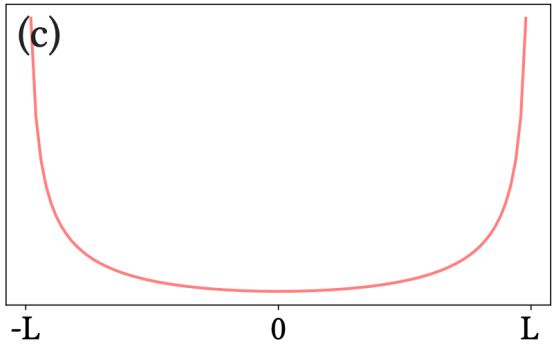


$\alpha = \beta = 2$



$\alpha = \beta = 0.5$

Displacement (L) Distribution

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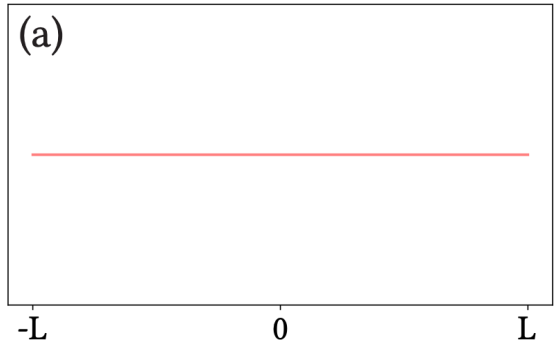

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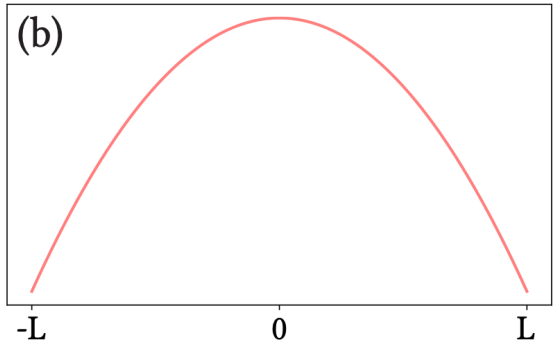

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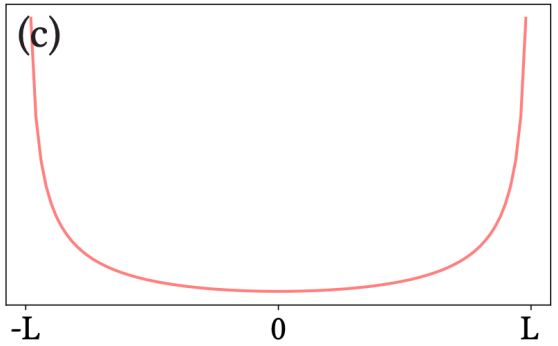

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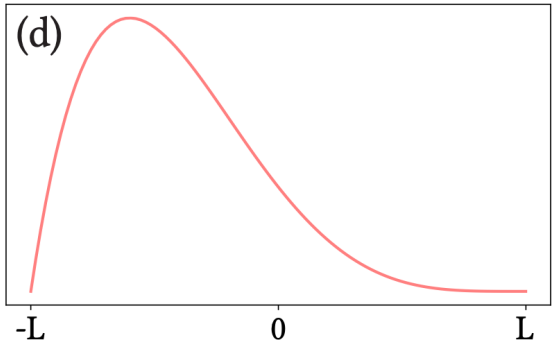

$\alpha = 2, \beta = 5$

Supported Workloads

Type	Workload	Data Loading		Operations	
		Method	% of data	R-W ratio	% of data
Insert only	A	Bulk loading	100%	-	-
Mixed reads & writes					

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Benchmarking Action

Metrics:

- Ingestion latency
- Overall operational latency

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Data Setup:

- 16M K-V pairs (~ 4GB)
- Key = 4B, Payload = 252B

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- AWS EC2 instance (t2.medium)
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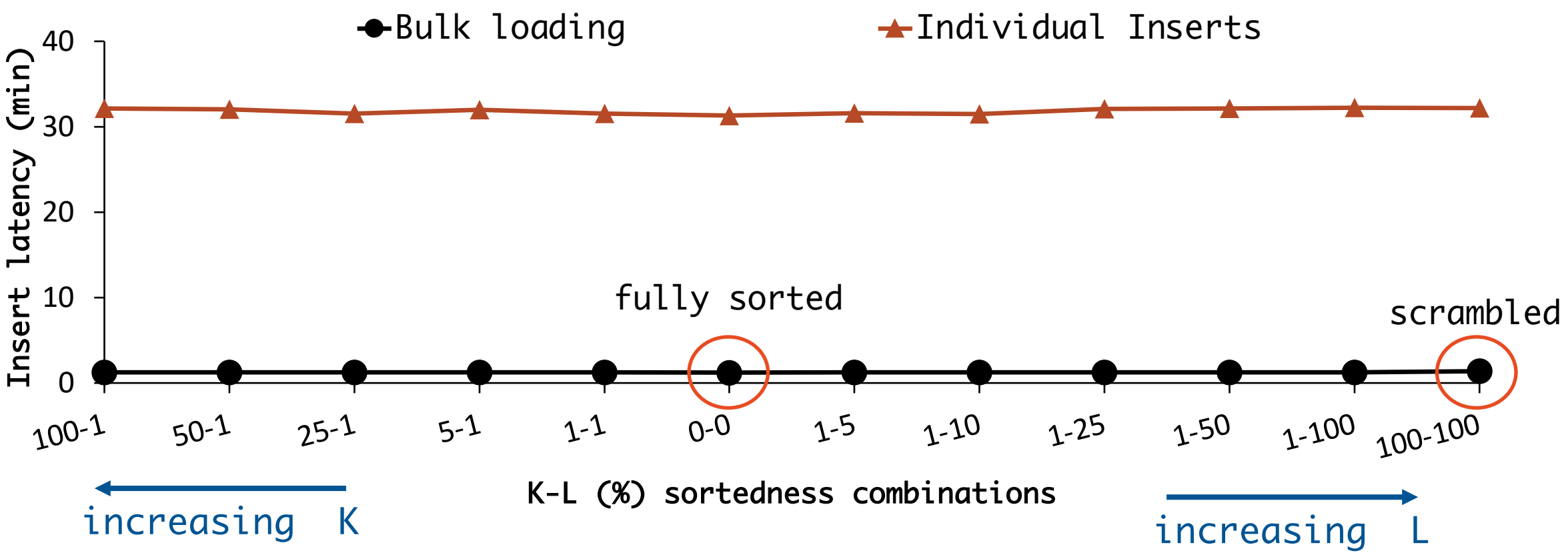
Default Index Setup:

- PostgreSQL (Unlogged tables)
- B-tree on key (id_col)

Raw Ingestion Performance



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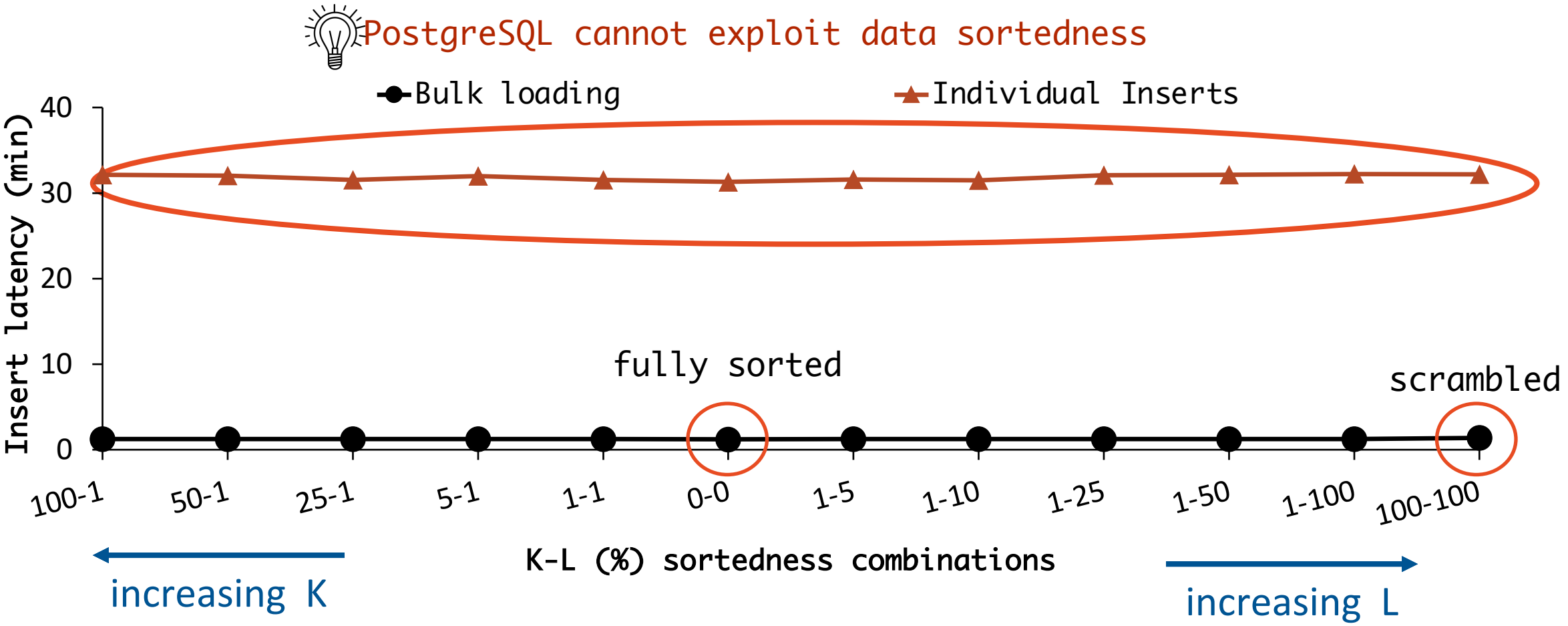
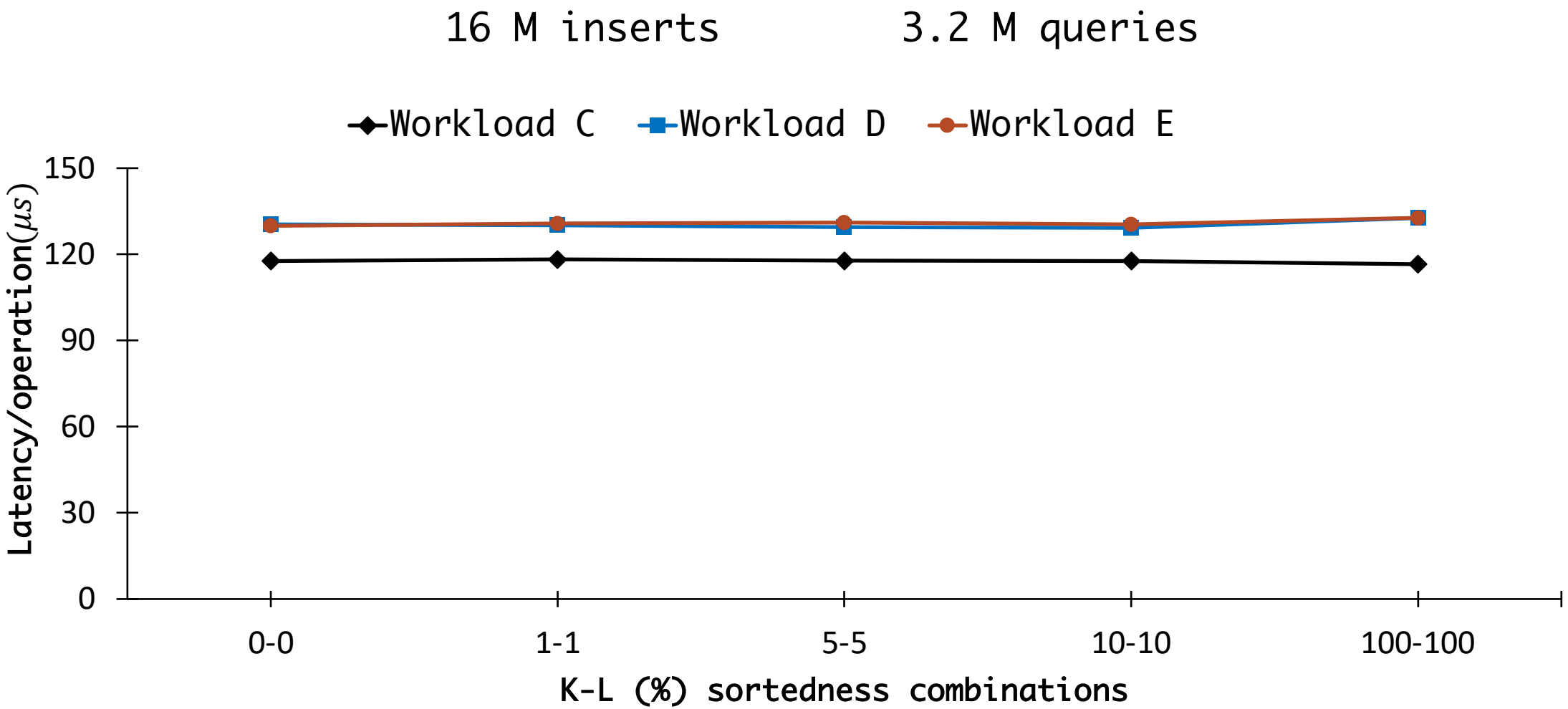
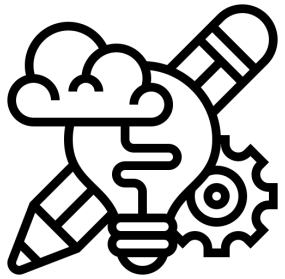


Mixed Workload Performance

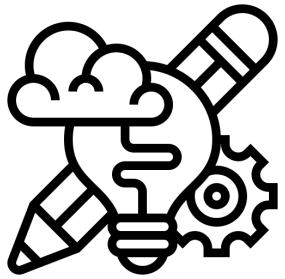


Column-Store Systems



Fundamental
design changes

Column-Store Systems



Fundamental
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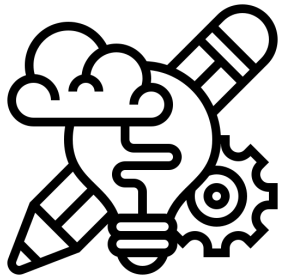
1. MonetDB

- ✕ invalidated by updates

Column-Store Systems



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2. Vertica
   - ✗ no live updates to sorted column

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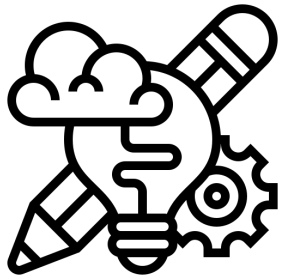


Fundamental
design changes

1. MonetDB
   - ✗ invalidated by updates
2. Vertica
   - ✗ no live updates to sorted column
3. Actian Vector
   - ⚠ PDT similar to b-trees

The Sortedness-Aware (SWARE) Paradigm

Key Ideas in SWARE Paradigm

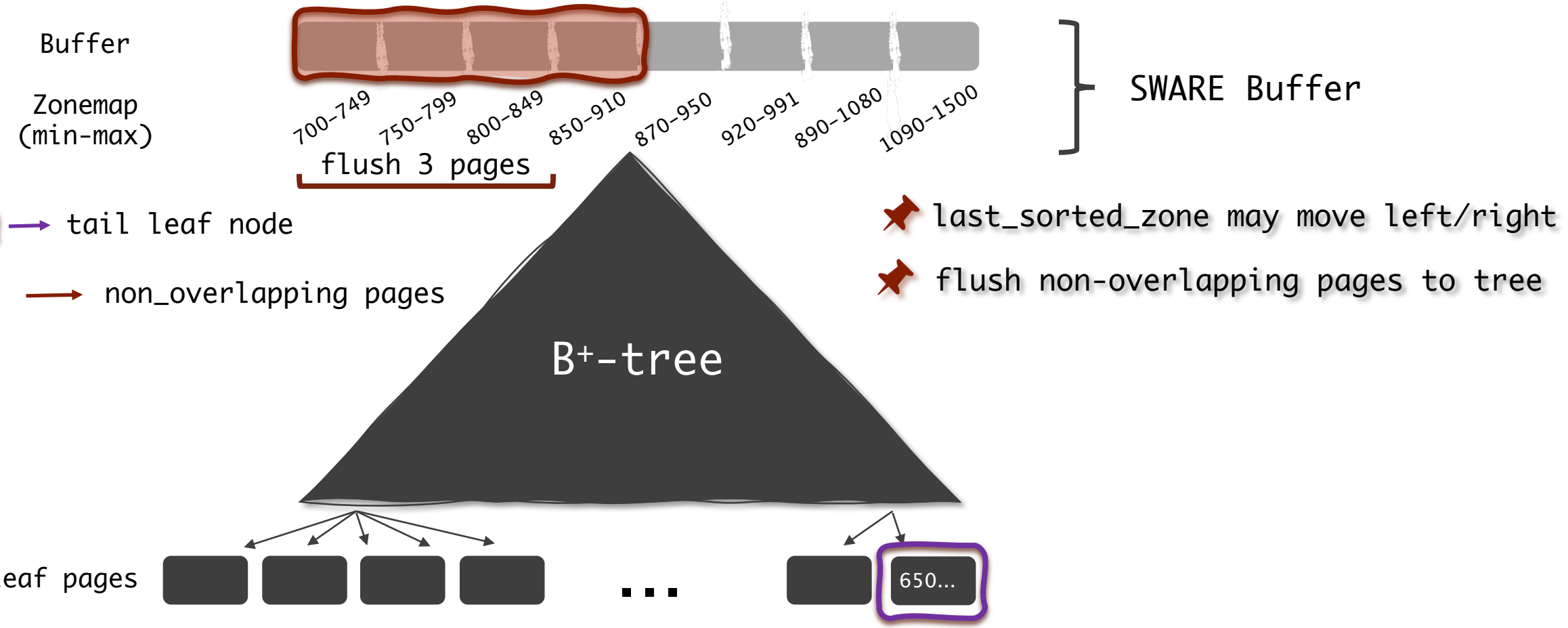
intelligent buffering

opportunistic bulk loading

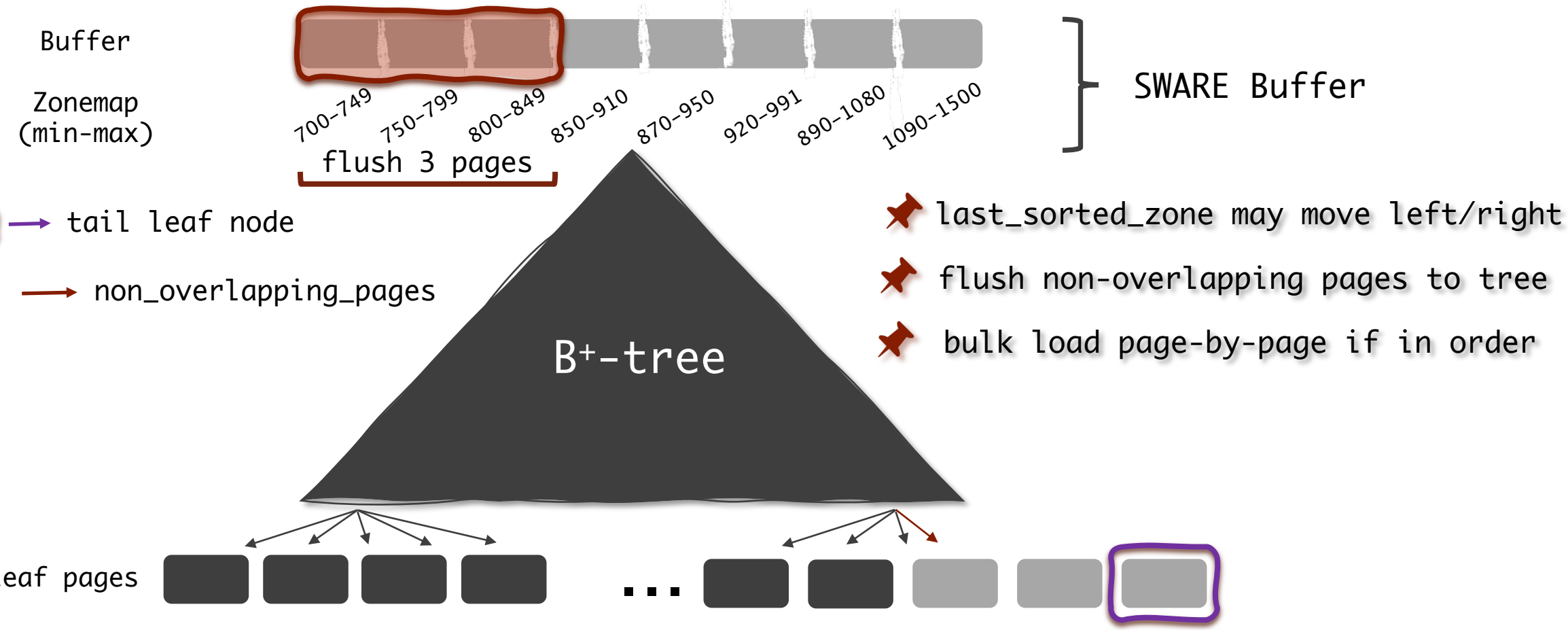
increased fill and split factor

Can be applied to any tree-index!

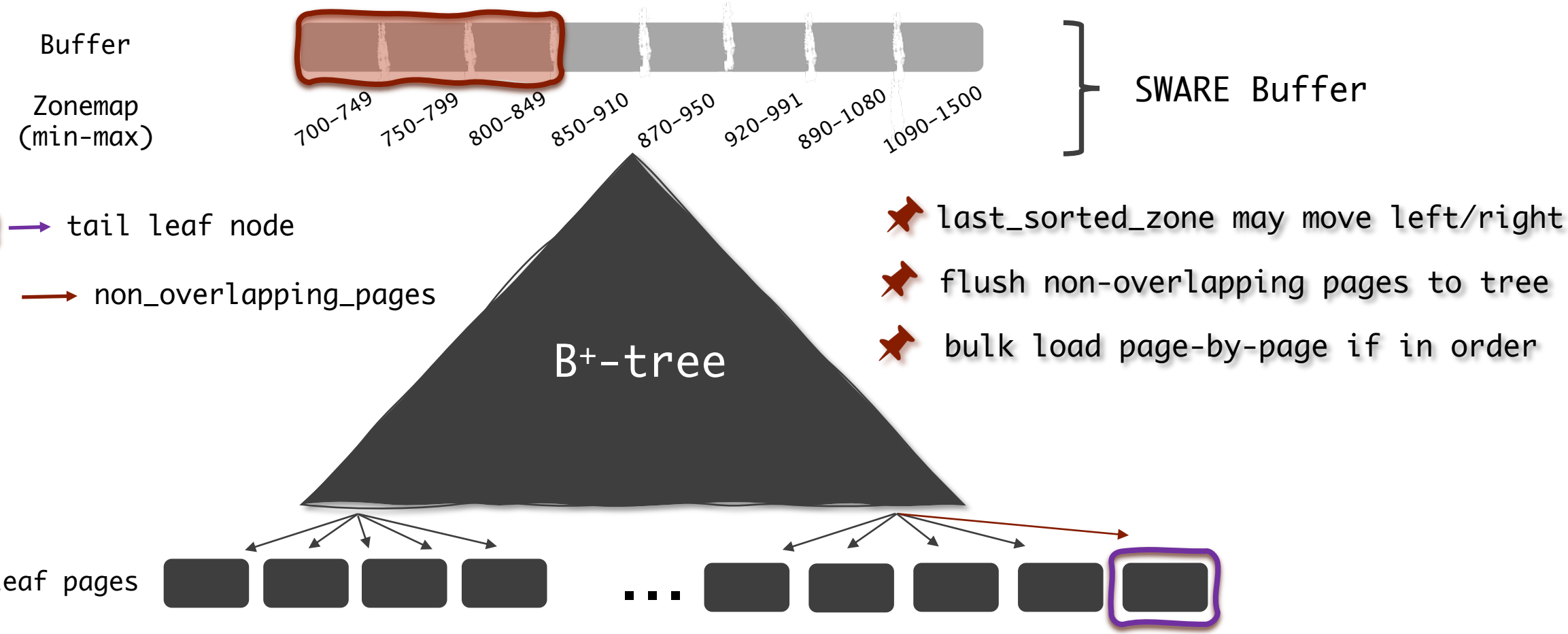
SWARE Ingestions



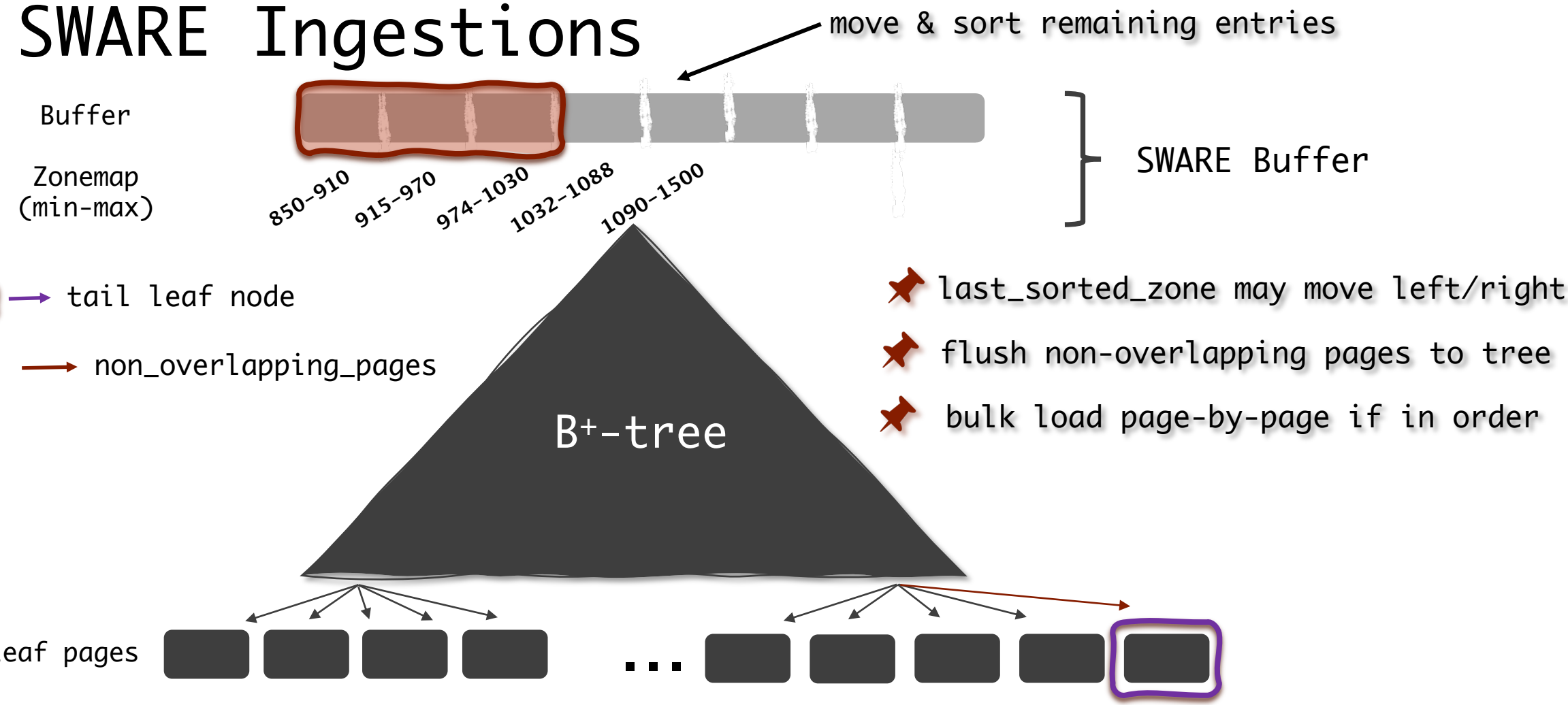
SWARE Ingestions



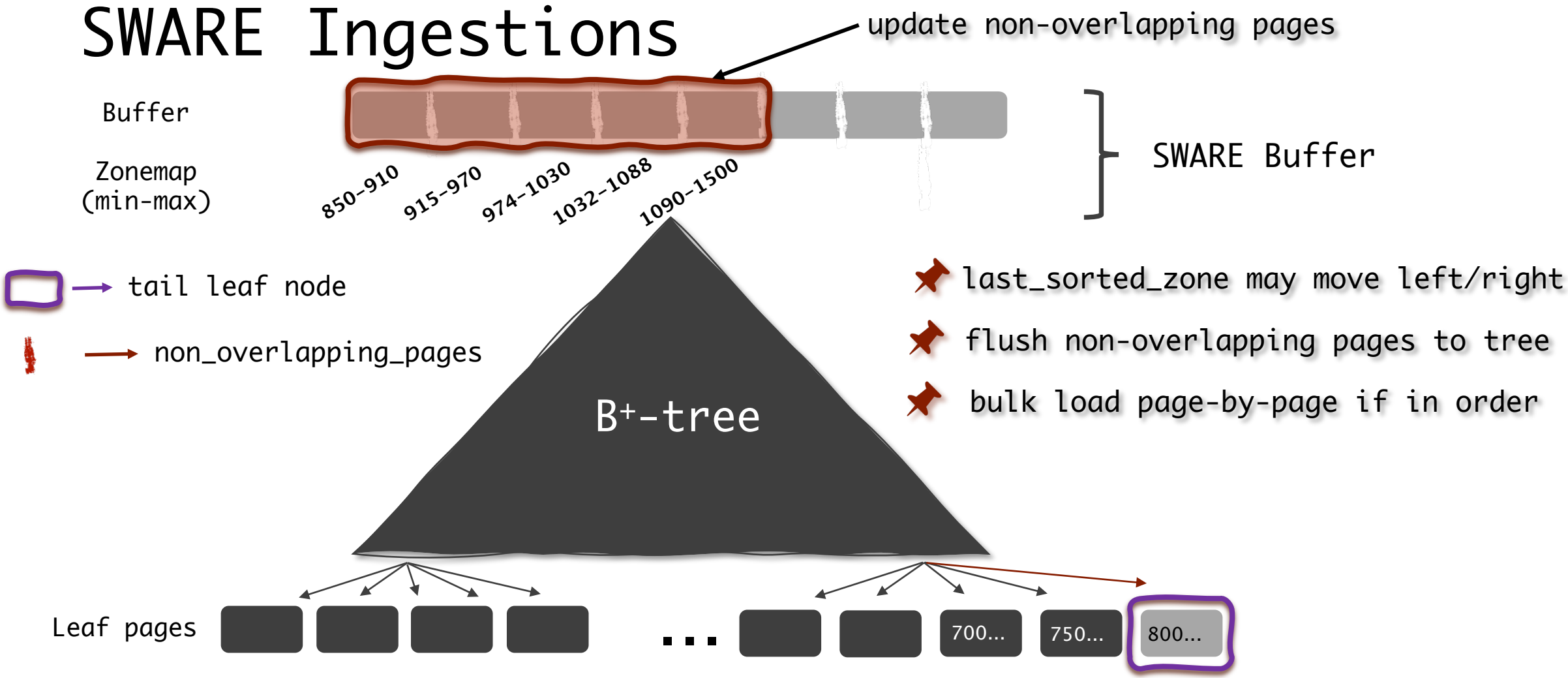
SWARE Ingestions



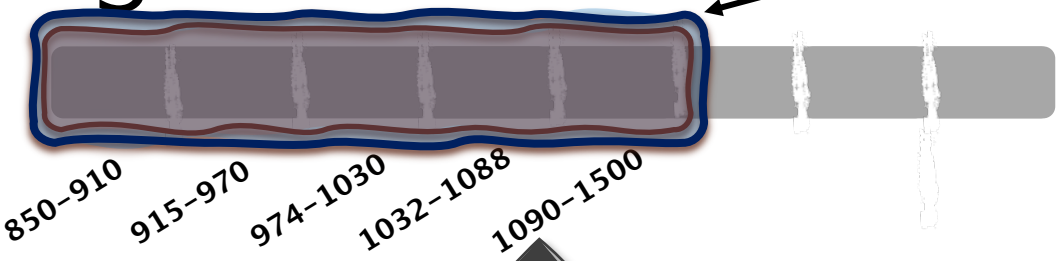
SWARE Ingestions



SWARE Ingestions



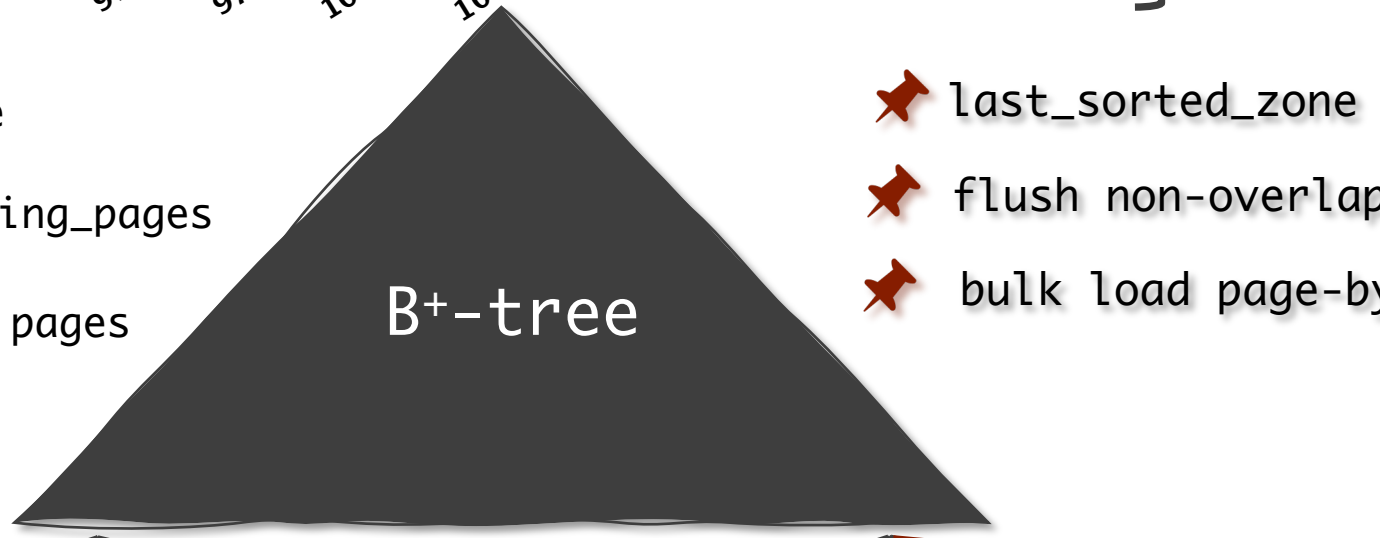
SWARE Ingestions



tail leaf node

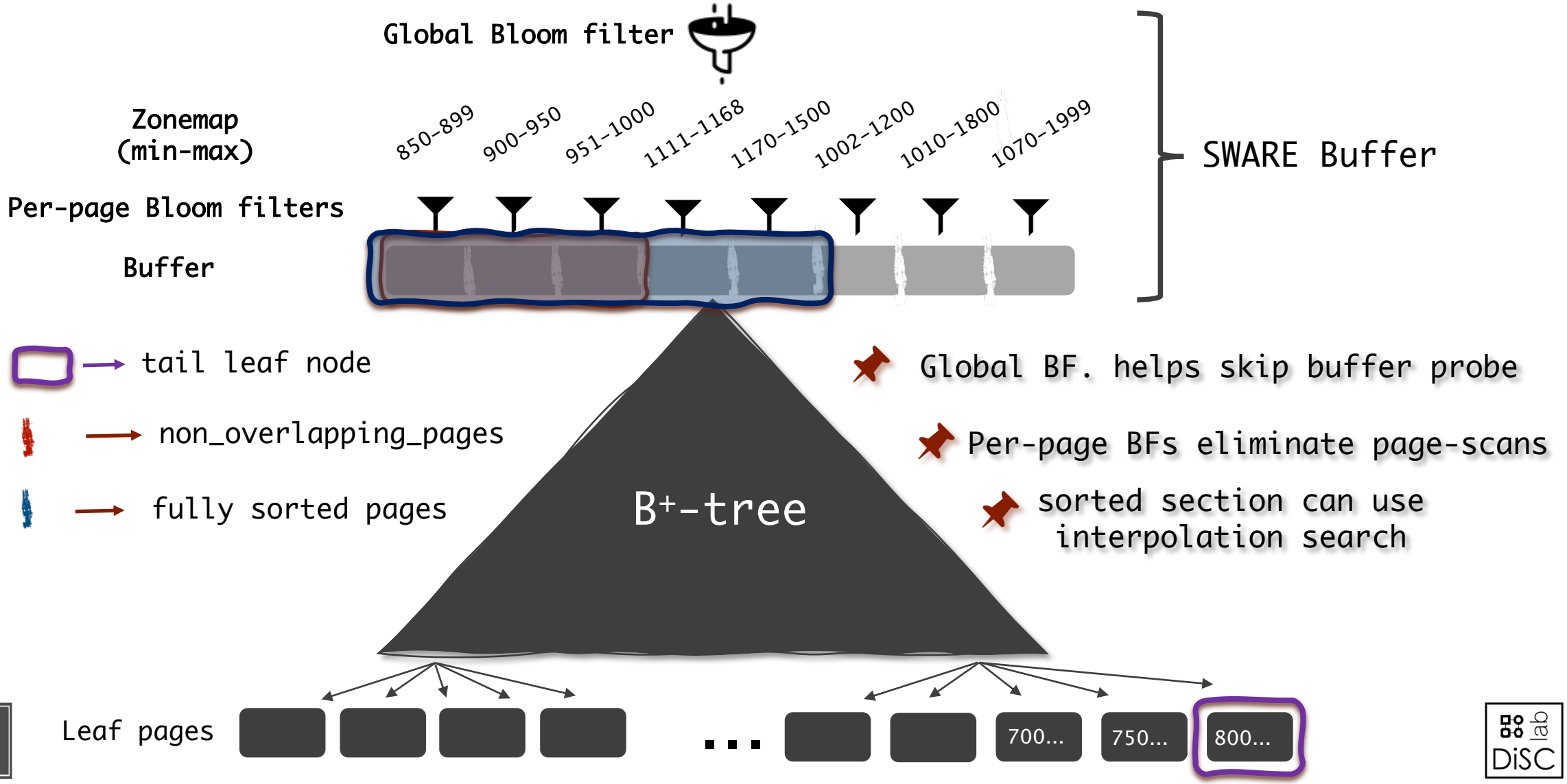
non_overlapping_pages

fully sorted pages

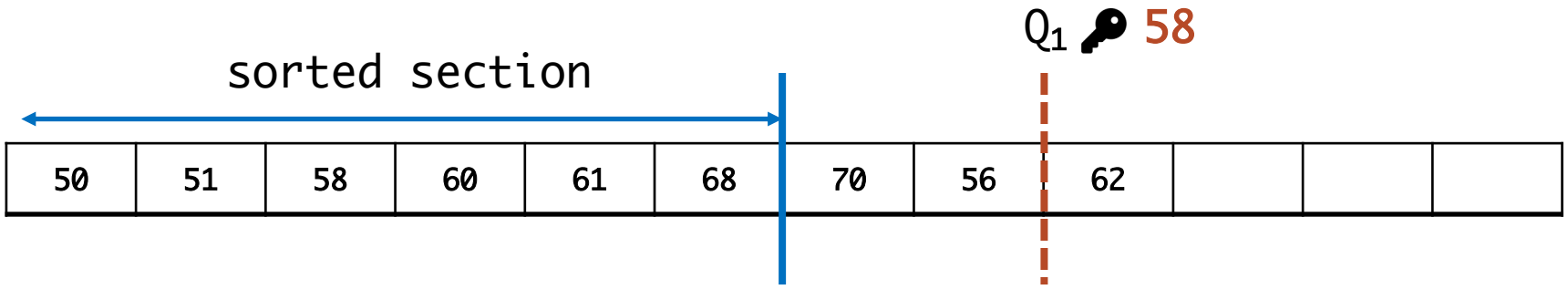


- last_sorted_zone may move left/right
- flush non-overlapping pages to tree
- bulk load page-by-page if in order

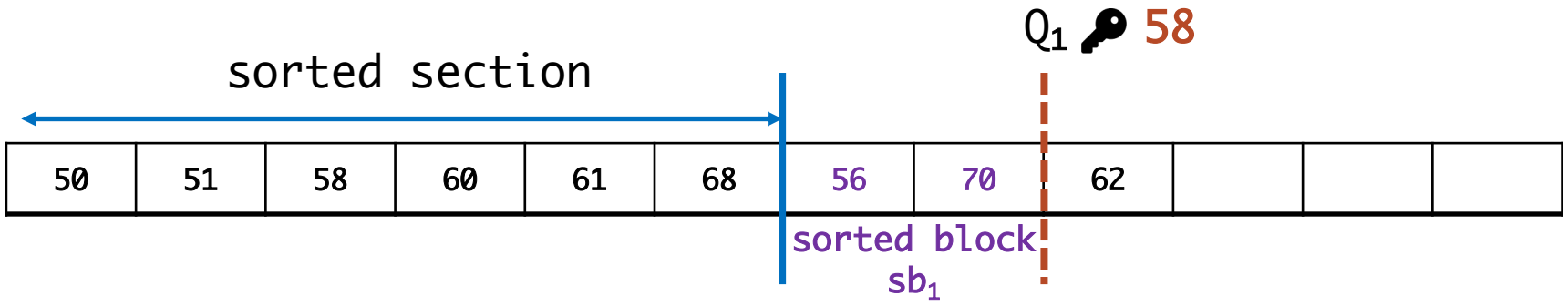
Overall Structure for Queries



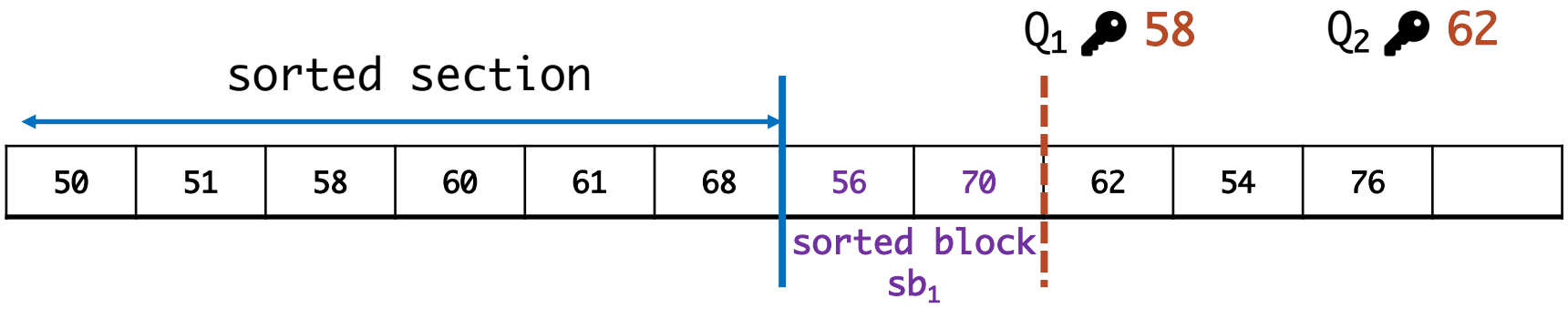
Query-driven Partial Sorting



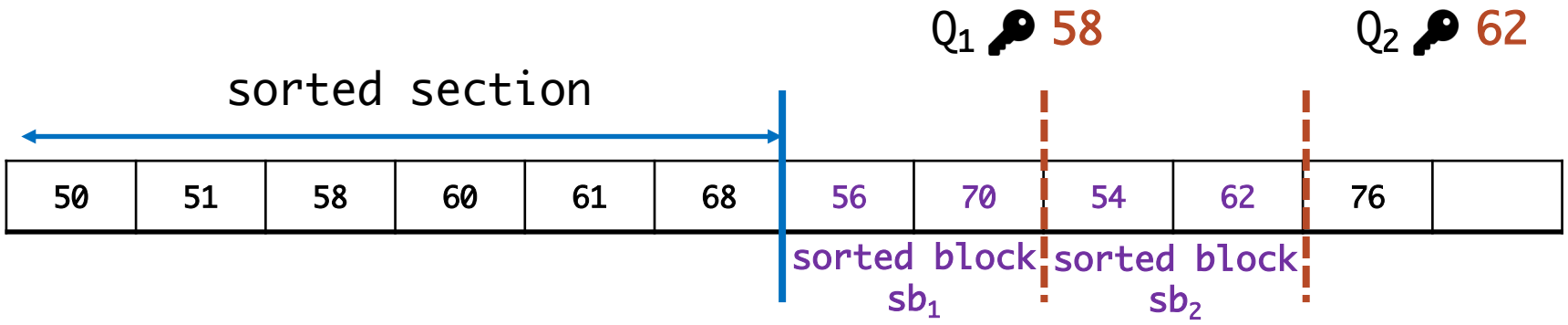
Query-driven Partial Sorting



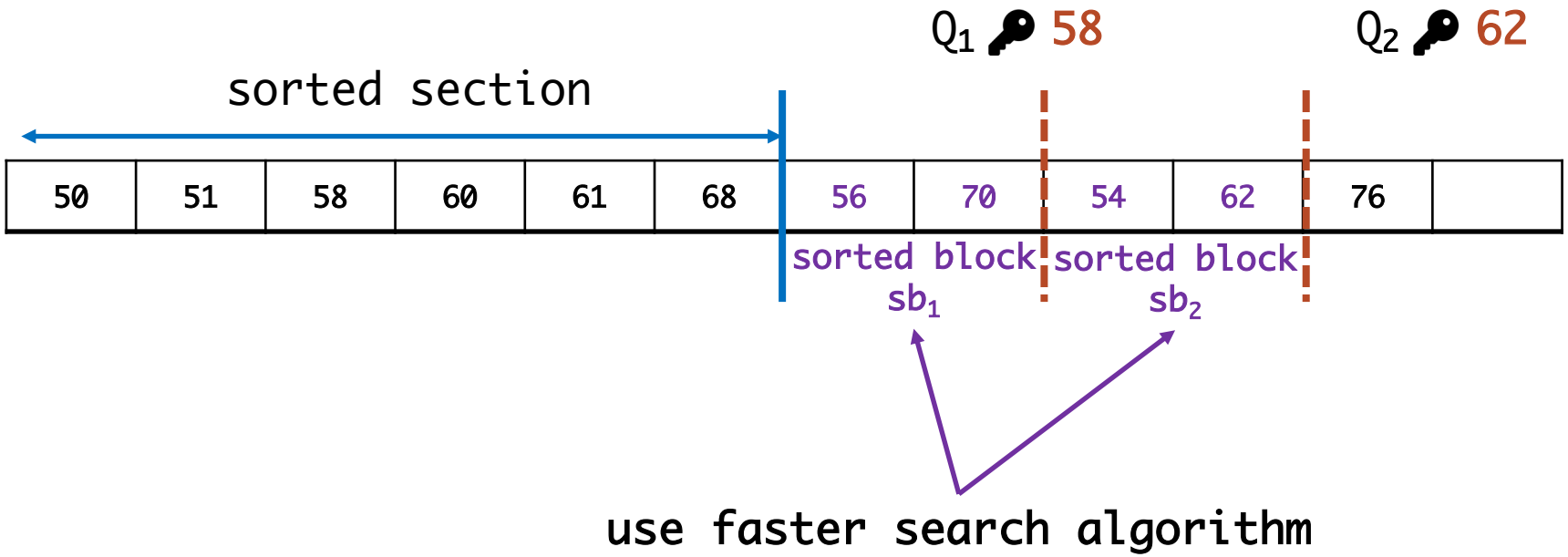
Query-driven Partial Sorting



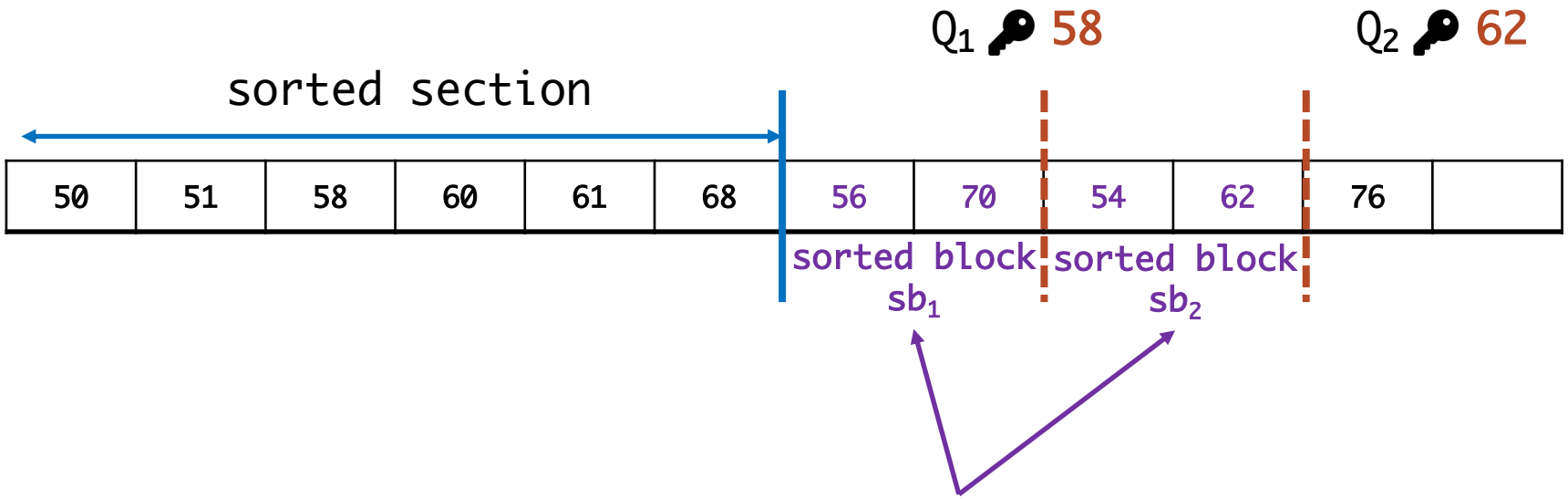
Query-driven Partial Sorting



Query-driven Partial Sorting



Query-driven Partial Sorting



Experimental Setup

Metrics:
1. Overall performance (speedup)
2. Raw performance (latency)

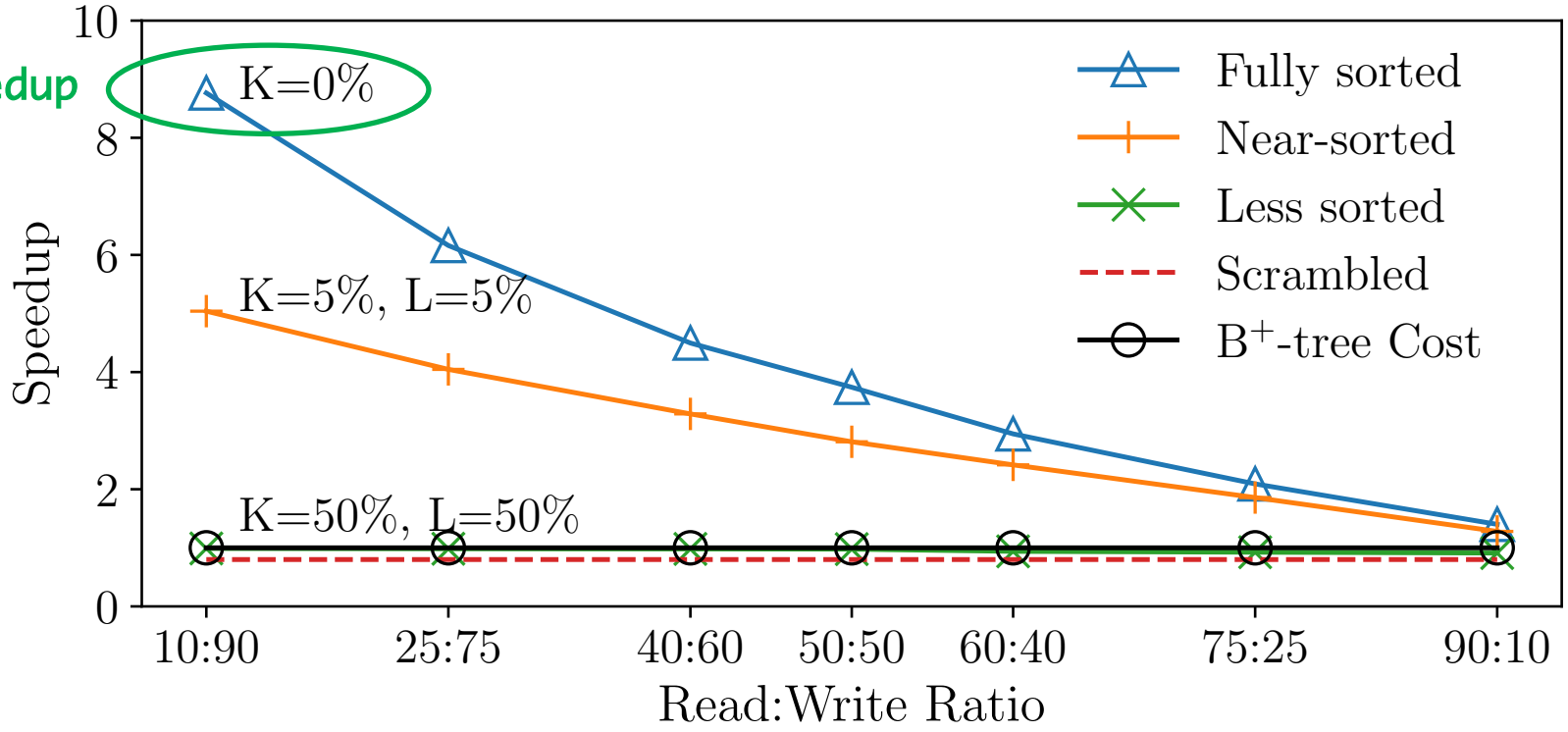
Workload Generator: **BoDS**
1. 500M Integer keys (~ 4GB)
2. Random lookups on existing keys

System Setup:
1. Intel Xeon Gold 5230
2. 2.1GHZ processor w. 20 cores
3. 384GB RAM, 28MB L3 cache

Default Index Setup:
1. Buffer = 40MB; flush <= 50%
2. BFs = 10 BPK; Murmur Hash
3. Split = 80:20; Bulk load = 95%

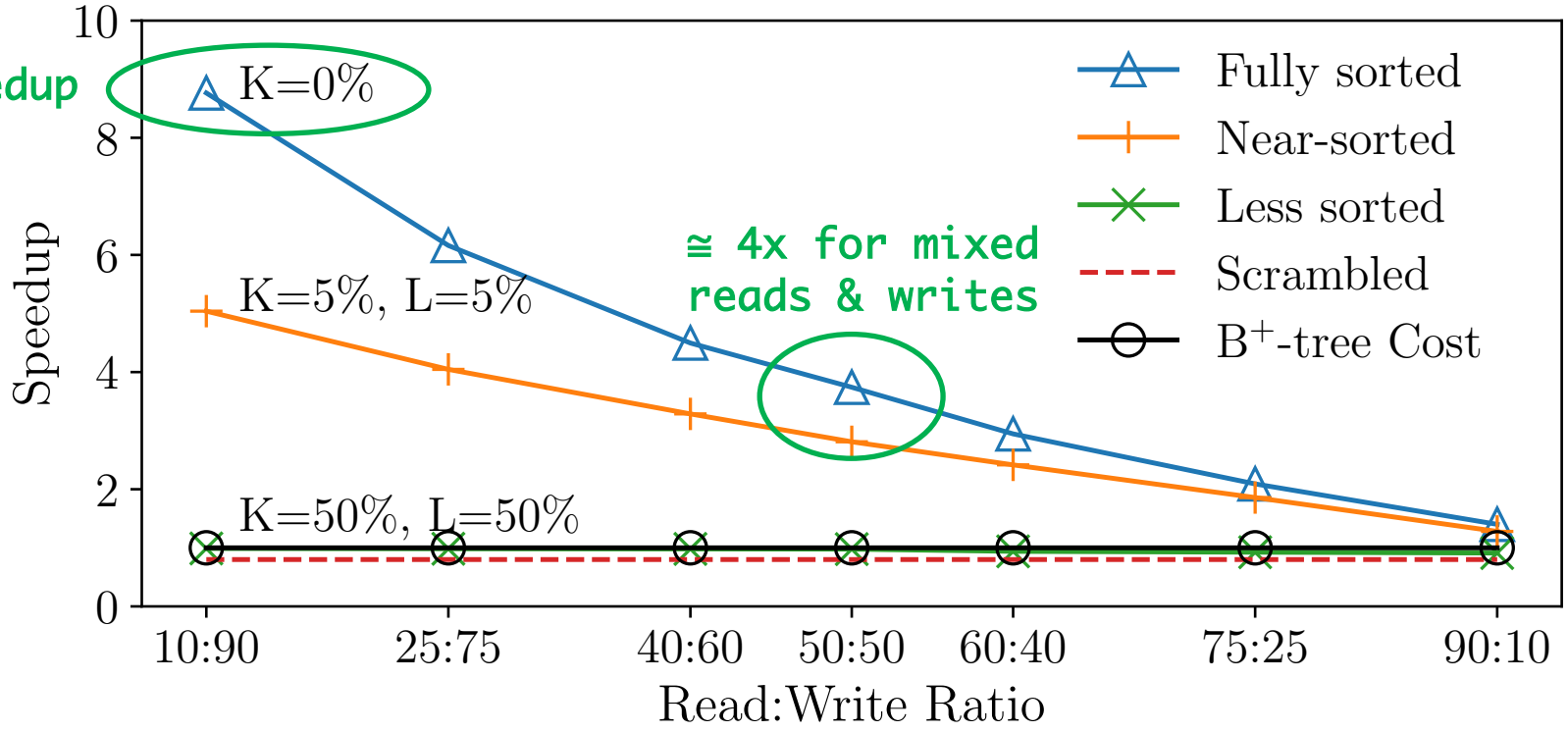
Overall Performance

≅ 9x speedup

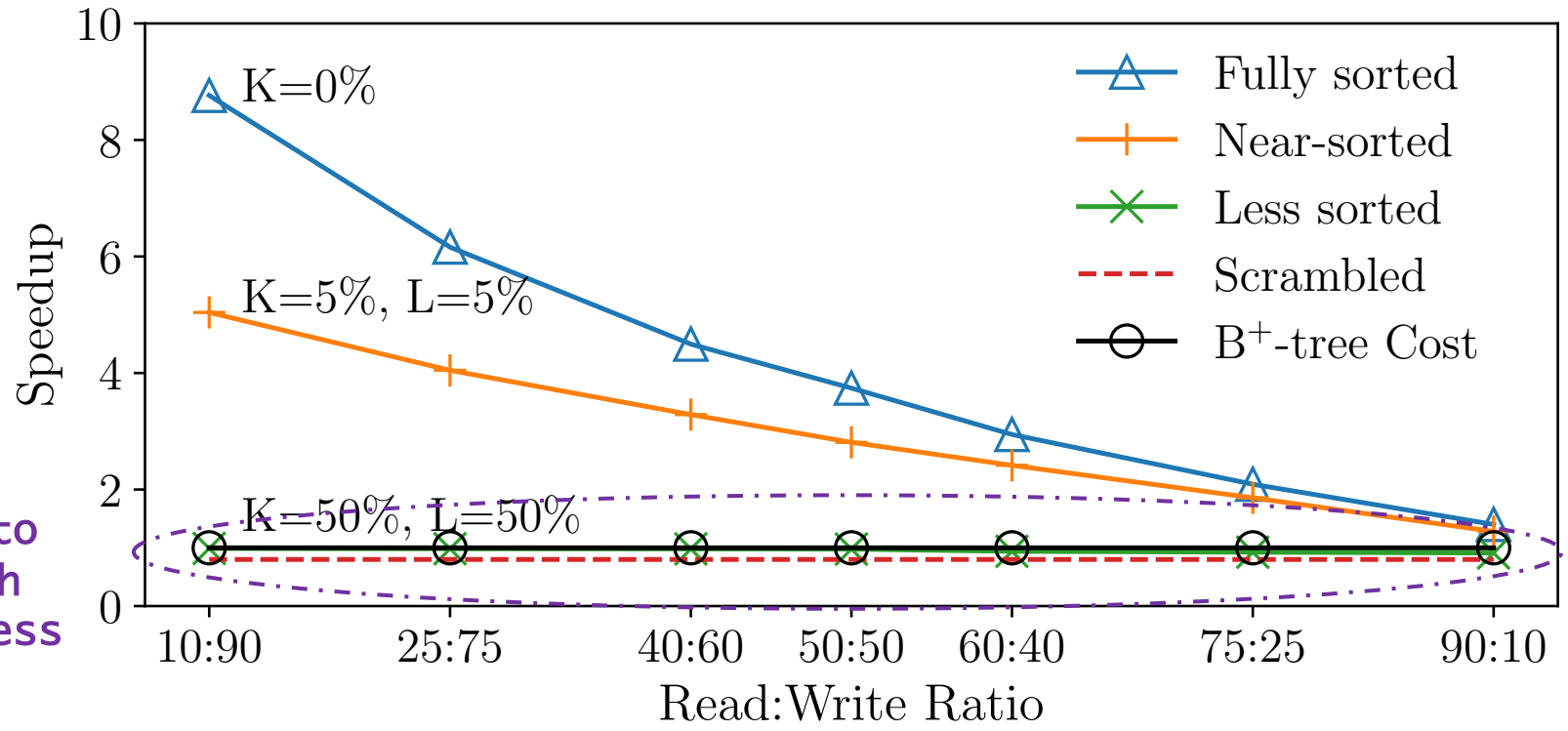


Overall Performance

≅ 9x speedup

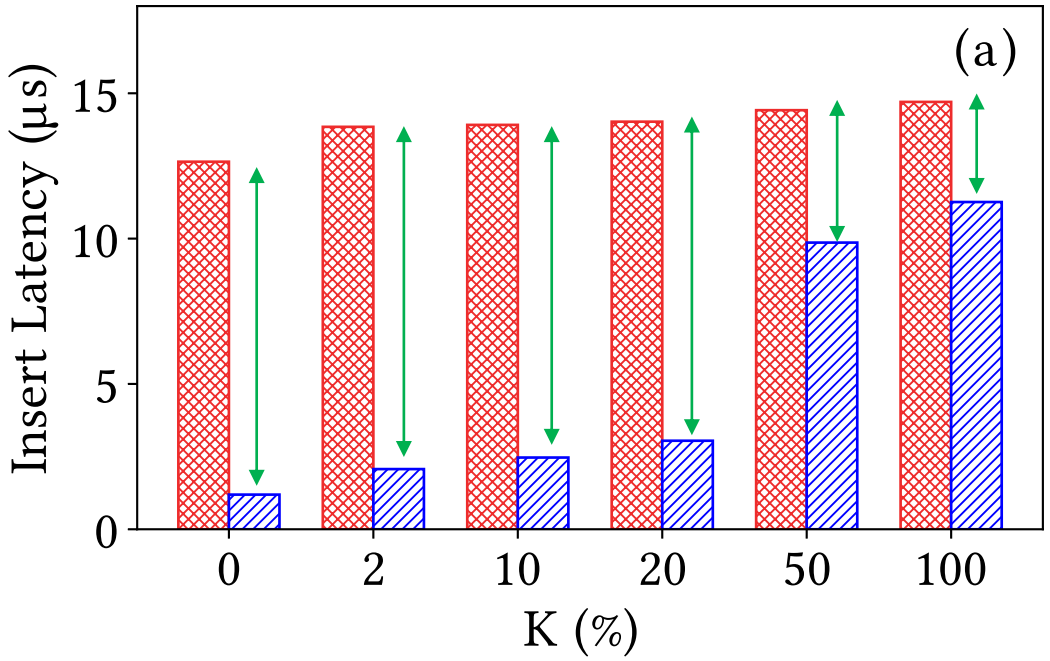


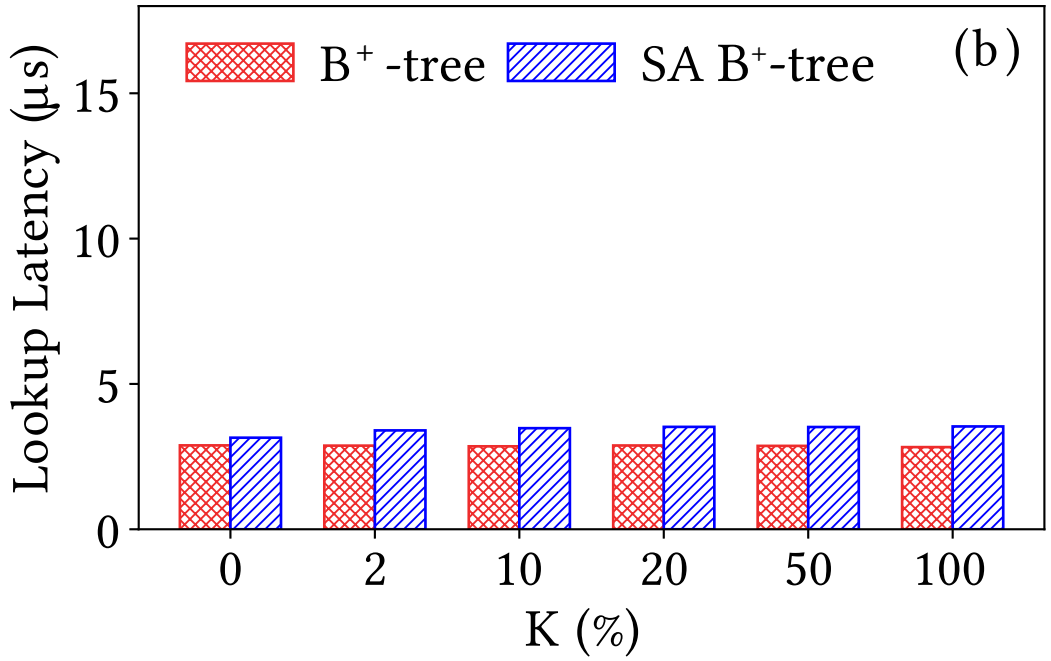
Overall Performance



comparable to B+-tree with less sortedness

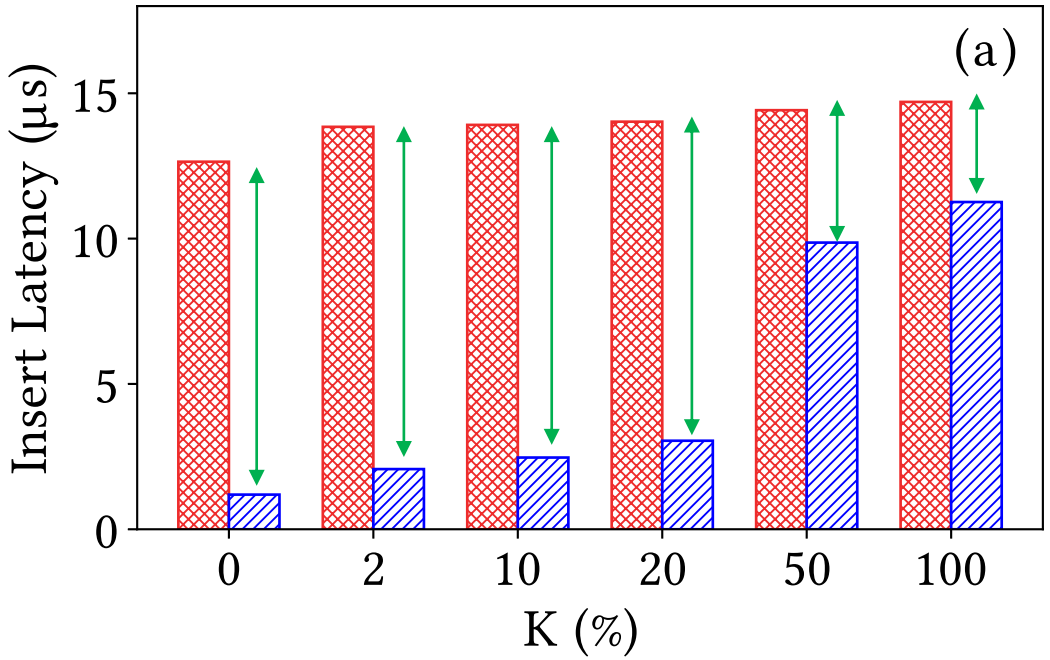
Raw Performance



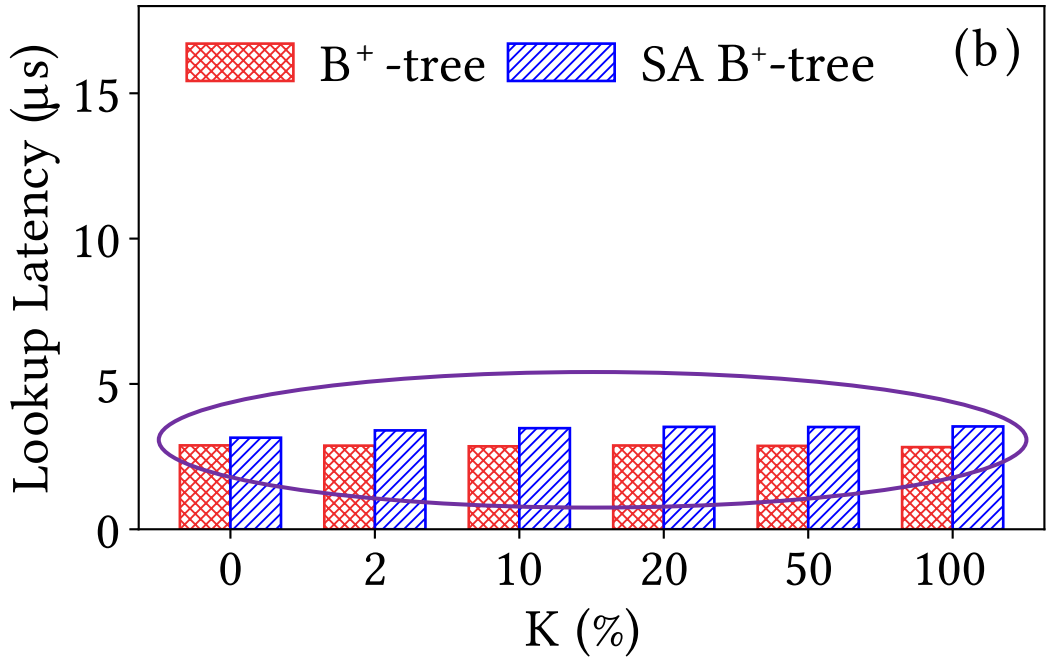


ingestion latency reduced between 27-90%

Raw Performance

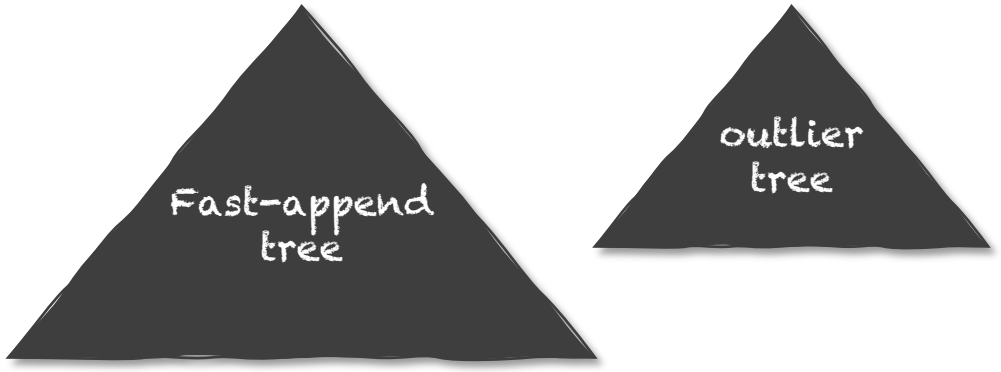


ingestion latency reduced between 27-90%

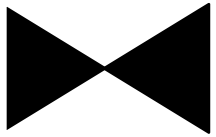


overhead in lookups between 5-26%

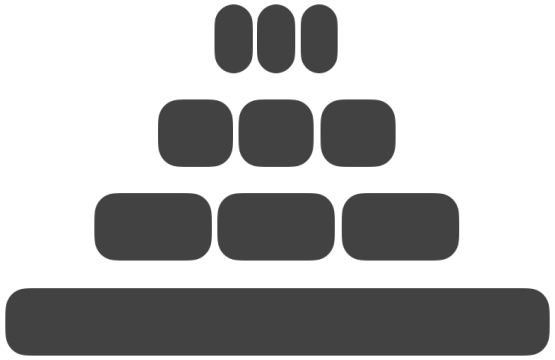
Future Work



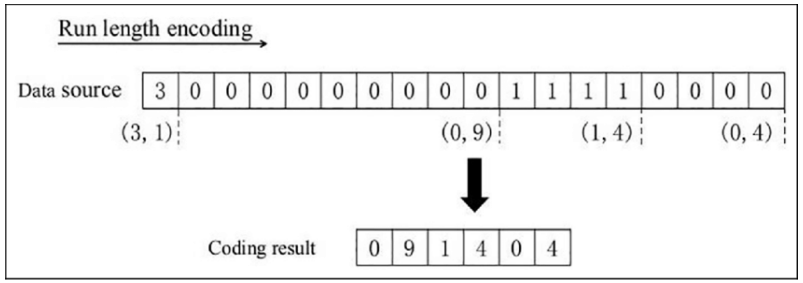
Dual B⁺-tree



Speed up SMJ for near-sorted data?



Can we build LSM-trees bottom up?



Can compression algorithms exploit sortedness?

BOSTON UNIVERSITY

DiSC lab

Summary

Identify “**sortedness**” as a resource

Smart buffering + bulk index appends = **faster** inserts

8.8x speedup with **SWARE** meta-design

Framework can be **extended** to other indexes

Thank You!