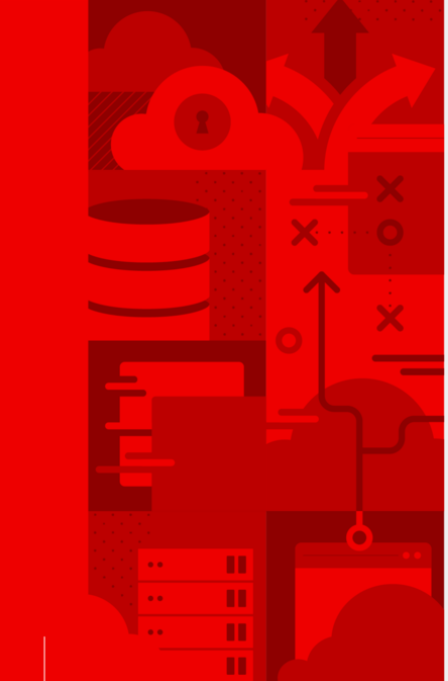

Modern BTree techniques

DMITRII DOLGOV

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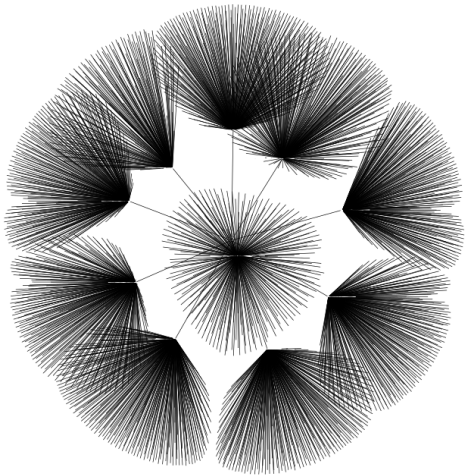

Red Hat

- D. Comet, ”Ubiquitous B-tree”, ACM Comp. Surv., vol. 11, no. 2, 1979.

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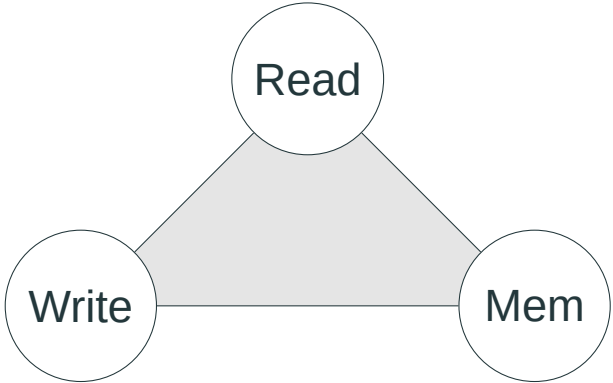
- Graefe, Goetz and Harumi A. Kuno. ”Modern B-tree techniques.” IEEE 27th International Conference on Data Engineering, 2011.

- RUM conjecture
- B-Tree
  - Key normalization & friends
  - SB-Tree
  - MDAM
- Hybrid, Bw-Tree, DPTree
- Trie
- Everything else

B-Tree	B^+-Tree	B_{link}-Tree	DPTree
wB^+-Tree	NV-Tree	FPTree	FASTFAIR
HiKV	Masstree	Skip List	ART
WORT	CDDS-Tree	Bw-Tree	HOT
KISS-Tree	VAST-Tree	FAST	HV-Tree
UB-Tree	LHAM	MDAM	Hybrid B^+-Tree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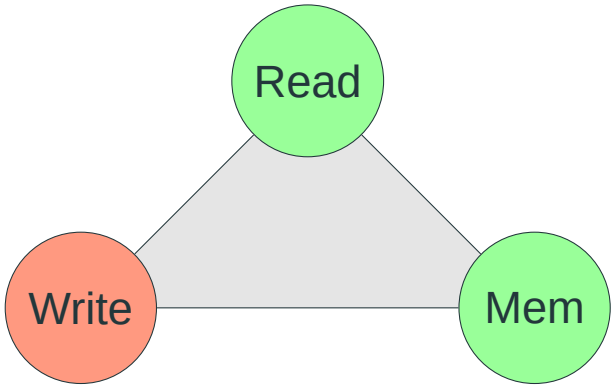

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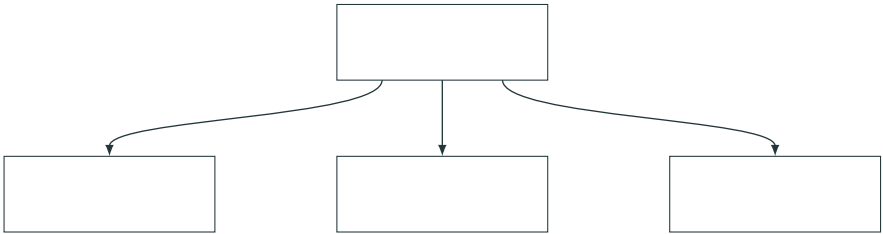
B+Tree



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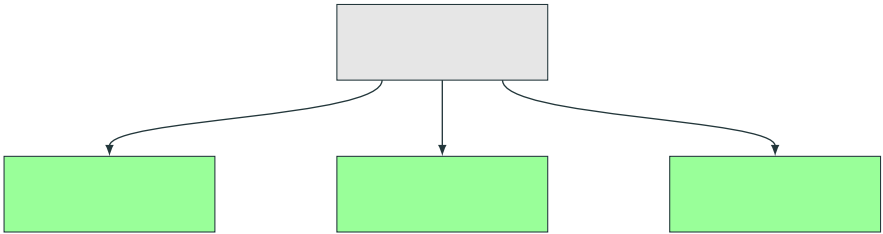

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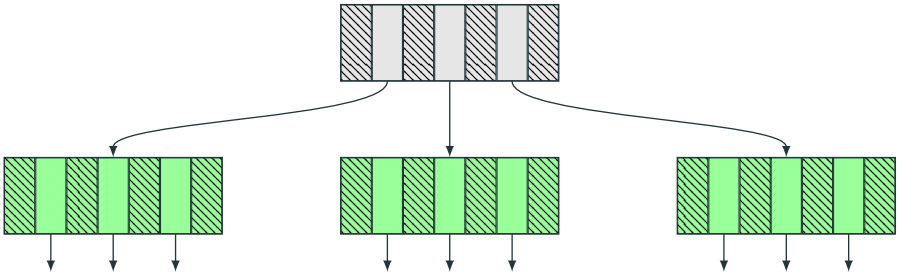

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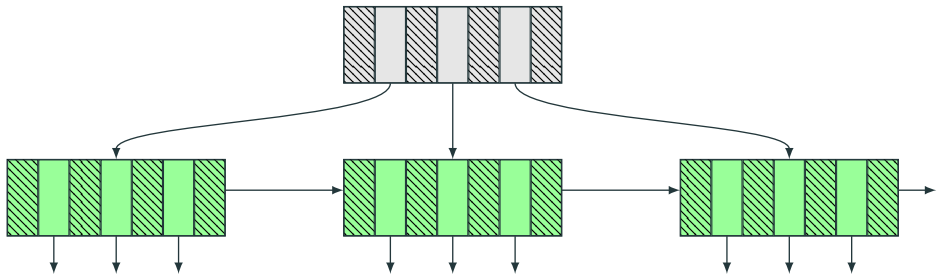

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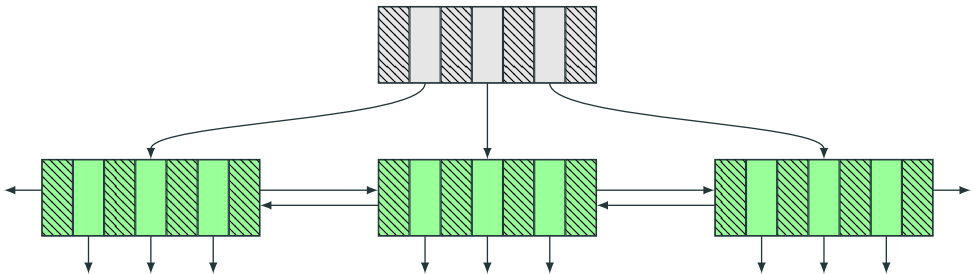

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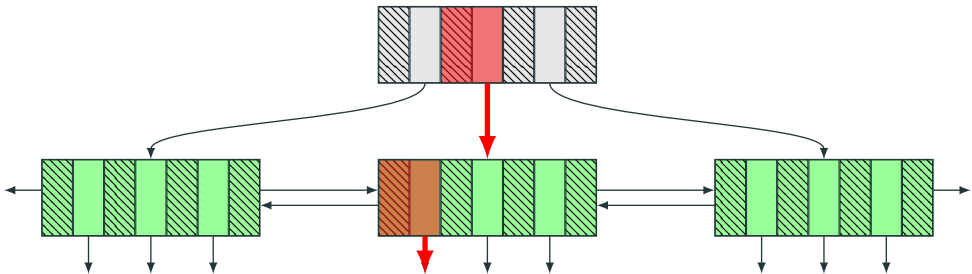

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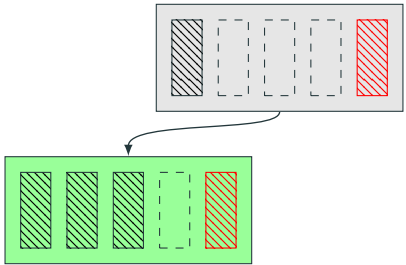

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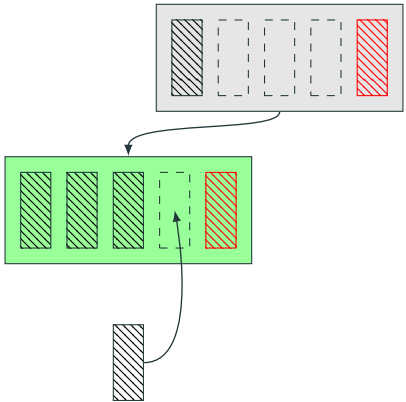

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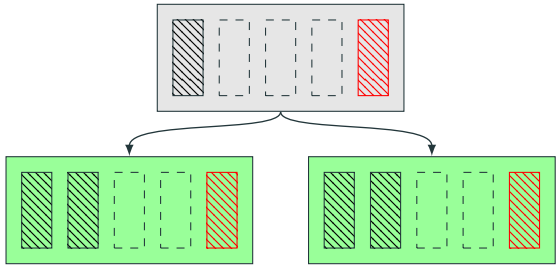

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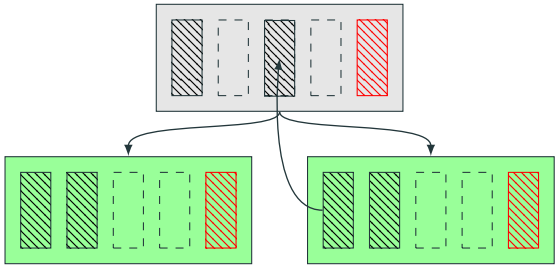

Page merge

”By adding periodic rebuilding of the tree, we obtain a data structure that is theoreticaly superior to standard B-trees in many ways. Our results suggest that rebalancing on deletion no only unnecessary but may be harmful.”

S. Sen and R. E. Tarjan, ”Deletion without rebalancing in multiway search trees.” ISAAC, pp. 832-841, 2009

Key normalization

1	”Dirk”	”Bart”	1 0..01 1 11..00 ∅ 1 10..10 ∅
2	”Todd”	Null	1 0..10 1 01..00 ∅ 0
Null	””	Null	0 1 ∅ 0

R. C. Singleton, ”An efficient algorithm for sorting with minimal storage”, Communications of the ACM, vol. 12, no.3 pp. 185-186, 1969

Prefix truncation

Smith Jack	01-02-2019
Smith Jane	02-03-2019
Smith James	03-04-2019

Prefix truncation

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Smith Jane	02-03-2019
Smith James	03-04-2019

Prefix truncation

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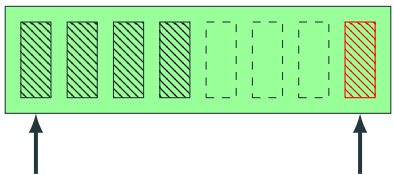
Prefix truncation



Red Hat

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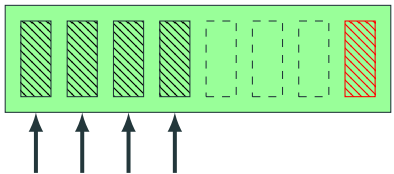
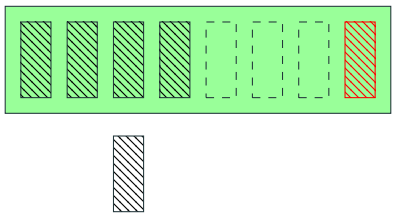


Red Hat

Dynamic prefix truncation



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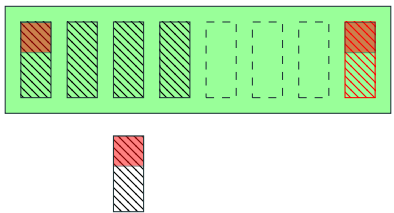
Dynamic prefix truncation



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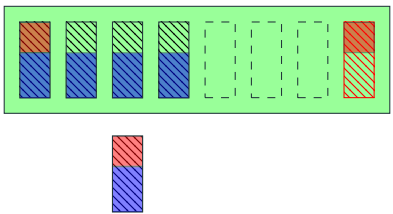
Dynamic prefix truncation



Suffix truncation

Cohen Richard	02-02-2019
Johnson David	04-02-2019
Miller Kevin	01-02-2019
Miller Mary	02-03-2019
Miller Steven	03-04-2019
Smith Susan	01-02-2019

R. Bayer, K. Unterauer, "Prefix B-trees", ACM Transactions on Database Systems, vol. 2, no. 1, pp. 11-26, 1977

Red Hat

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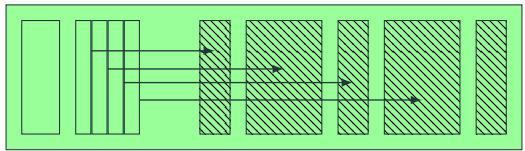
Indirection vector



G. Graefe, Per-Ake Larson, ”B-tree indexes and CPU caches”, International Conference on Data Engineering, pp. 349-358, 2001

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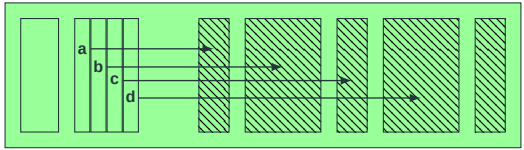

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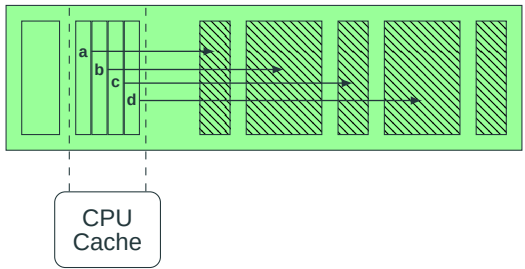

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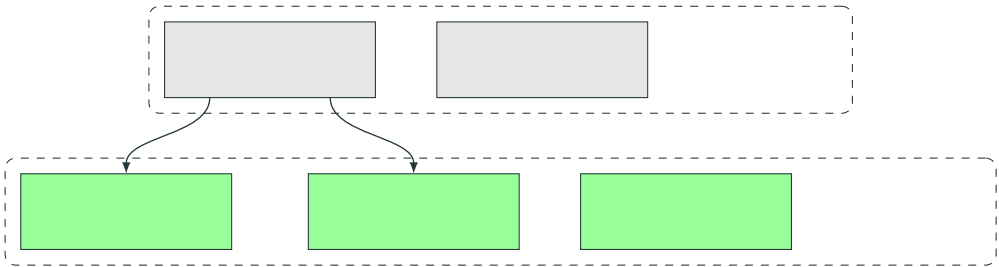
SB-tree



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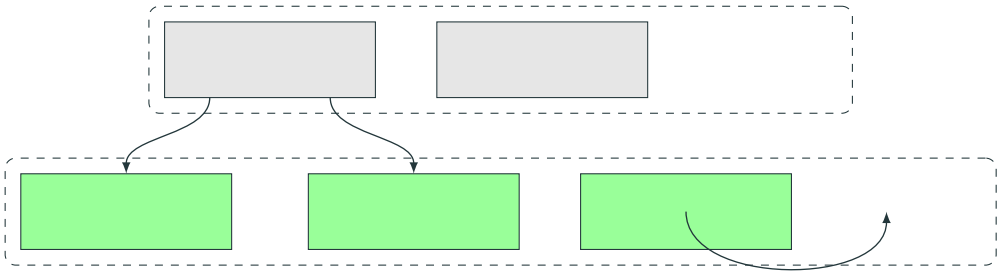

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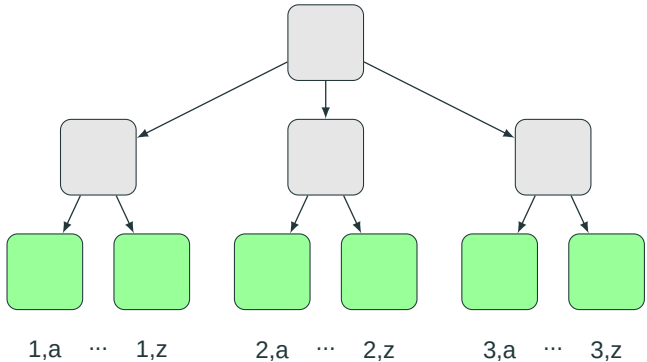
Multidimentional Access Method



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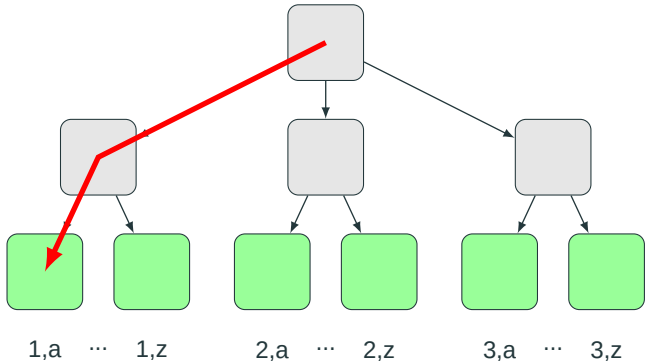

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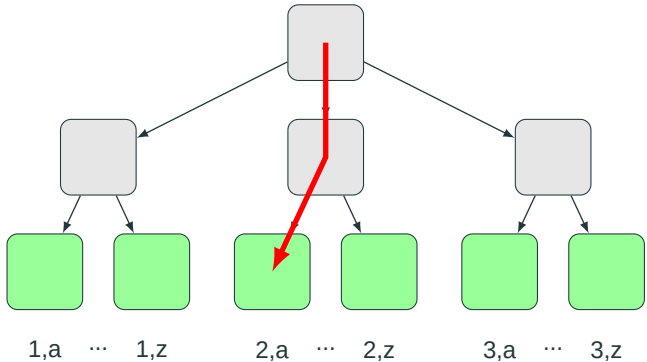

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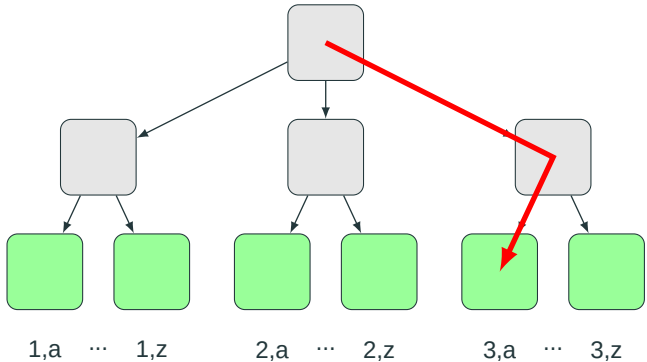

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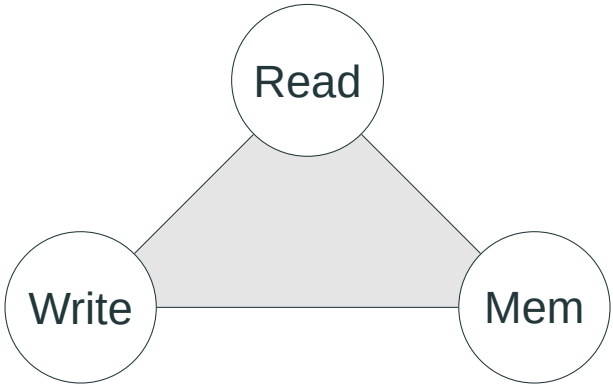
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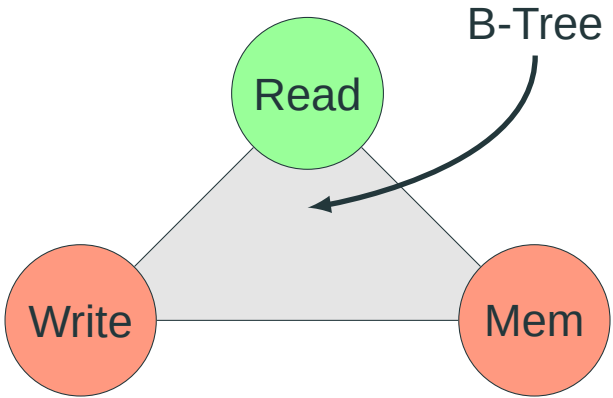

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T. Grust et al. (Hrsg.): Datenbanksysteme für Business, Technologie und Web (BTW 2019),
Lecture Notes in Informatics (LNI), Gesellschaft für Informatik, Bonn 2019 77

Waves of misery after index creation

Nikolaus Glombiewski,[1] Bernhard Seeger,[2] Goetz Graefe[3]

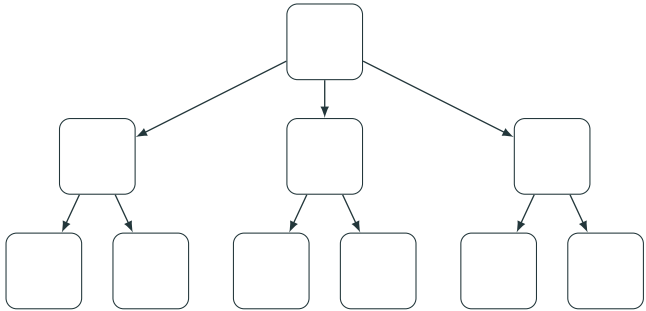
Abstract: After creation of a new b-tree, the ordinary course of database updates and index maintenance causes waves of node splits. Thus, a new index may at first speed up database query processing but then the first "wave of misery" requires effort for frequent node splits and imposes spikes of buffer pool contention and of I/O. Waves of misery continue over multiple instances although eventually the waves widen, flatten, and spread further apart. Free space in each node left during index creation fails to prevent the problem; it merely delays the onset of the first wave. We have found a theoretically sound way to avoiding these waves of misery as well as some simple and practical means to reduce their amplitude to negligible levels. Experiments demonstrate that these techniques are also effective. Waves of misery occur in databases and in key-value stores, in primary and in secondary b-tree indexes, after load operations, and after b-tree reorganization or rebuild. The same remedies apply with equal effect.

Keywords: Indexing, Bulk Loading, B-tree

1 Introduction

The purpose of adding an index to a database table is to improve the performance of query processing. Unfortunately, after an initial "honey moon" of using a new index and of enjoying fast queries, the index may grow and require many node splits – thus creating a spike in buffer pool contention and I/O activity. In other words, the index may actually reduce query performance or at least fail to achieve the expected performance. Consider the following example. First, a new secondary b-tree index enables fast look-ups and fast ordered scans. In order to absorb updates without node splits, each node might start with 10% free space – often a parameter of index creation. However, once the table and the

Partitioned B-tree



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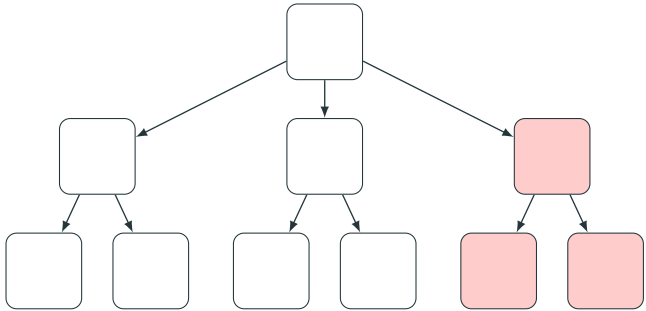

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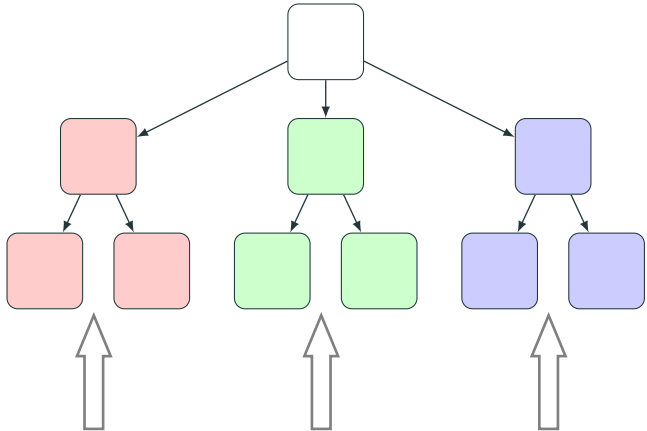
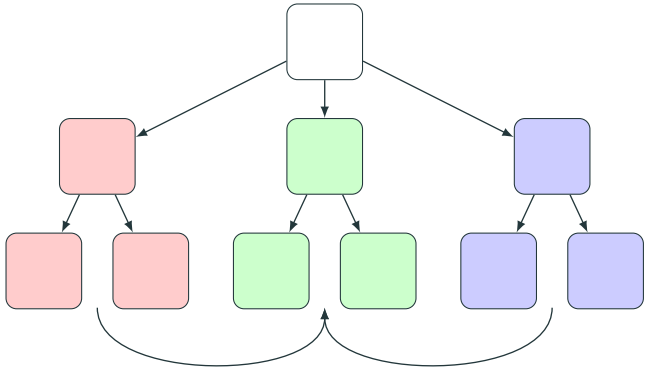


G. Graefe, ”Sorting and indexing with partitioned B-Trees”, Classless Inter Domain Routing, 2003

Partitioned B-tree



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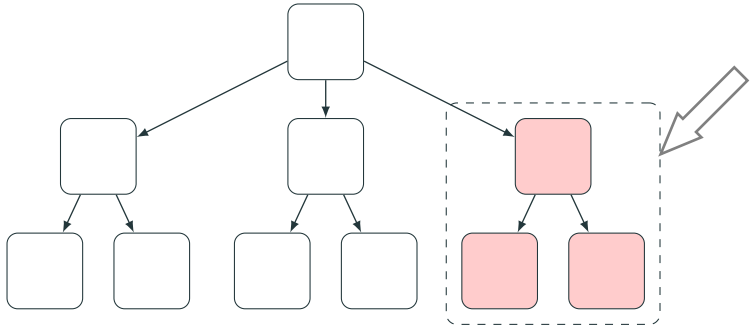

Riegger Christian, Vincon Tobias, Petrov Ilia. (2017). Write-optimized indexing with partitioned b-trees. 296-300.

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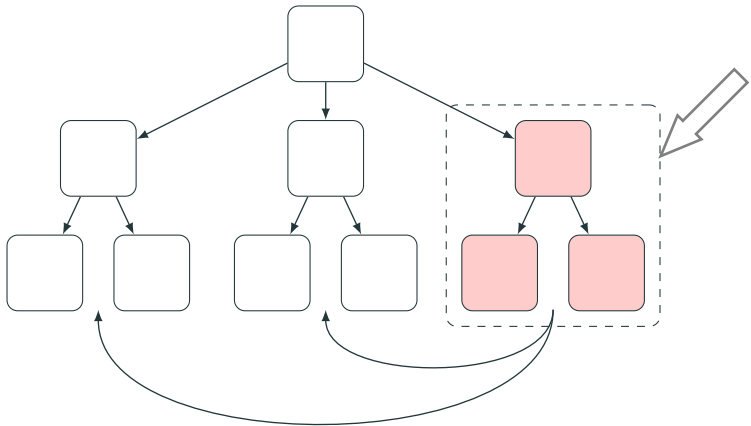

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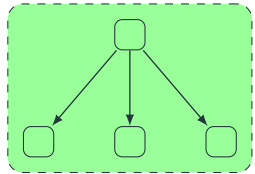
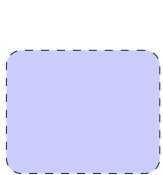
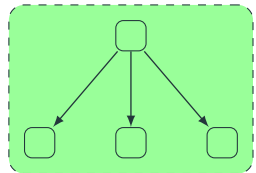
Hybrid indexes



Huanchen Zhang, David G. Andersen, Andrew Pavlo, Michael Kaminsky, Lin Ma, and Rui Shen. 2016. Reducing the Storage Overhead of Main-Memory OLTP Databases with Hybrid Indexes. In Proceedings of the 2016 International Conference on Management of Data (SIGMOD '16). Association for Computing Machinery, New York, NY, USA, 1567–1581.

Hybrid indexes





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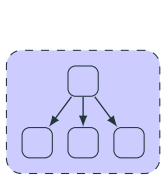

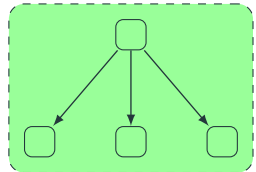

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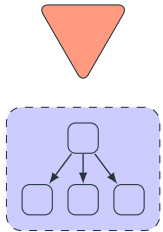

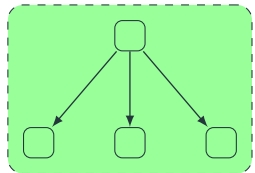

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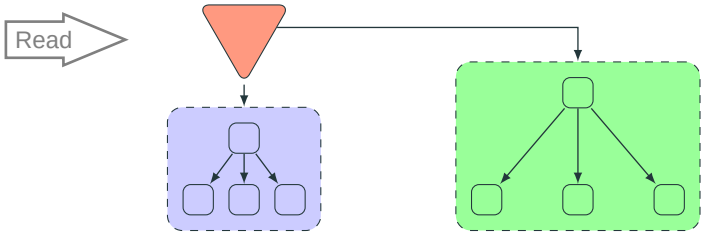

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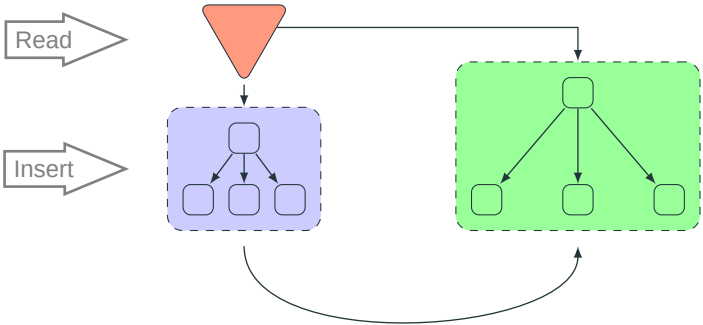

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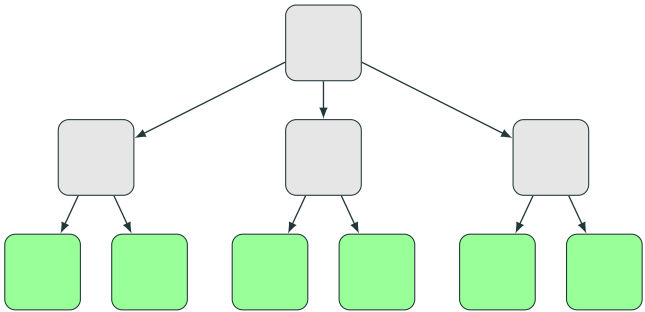
Bw-Tree



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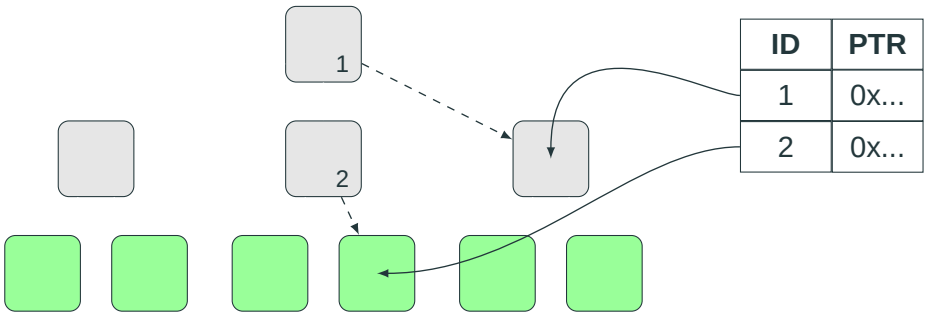

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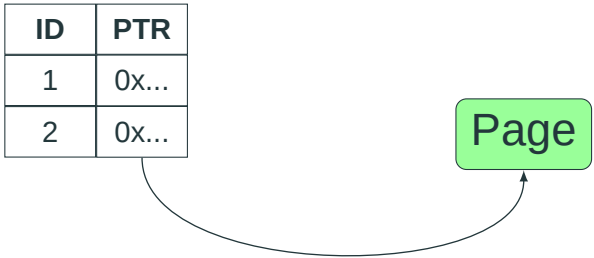

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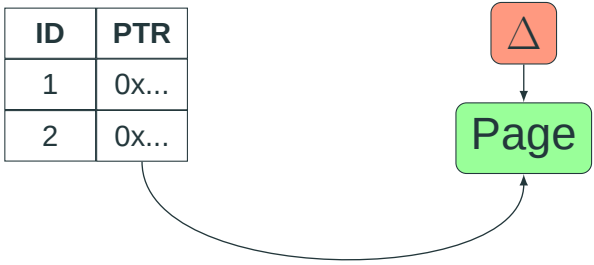

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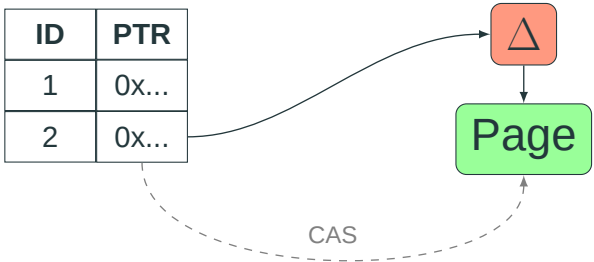

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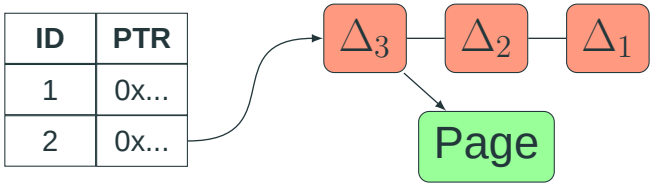

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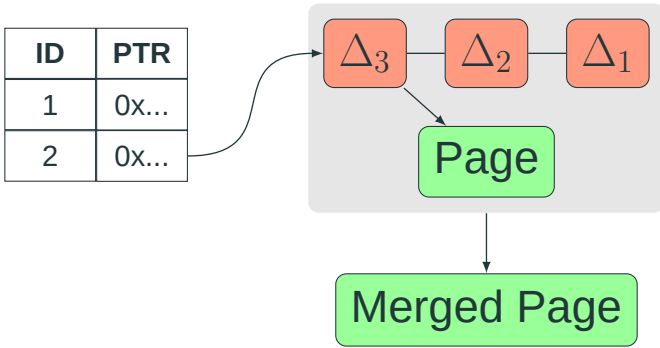

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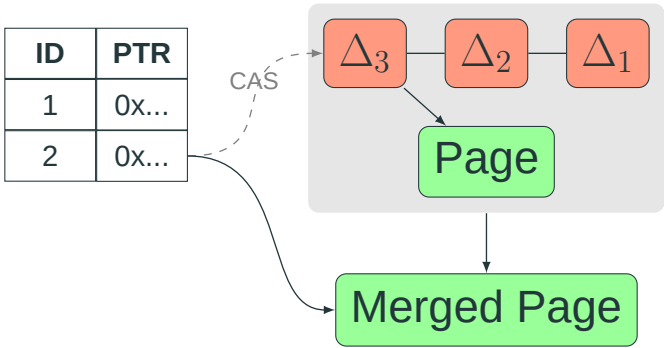

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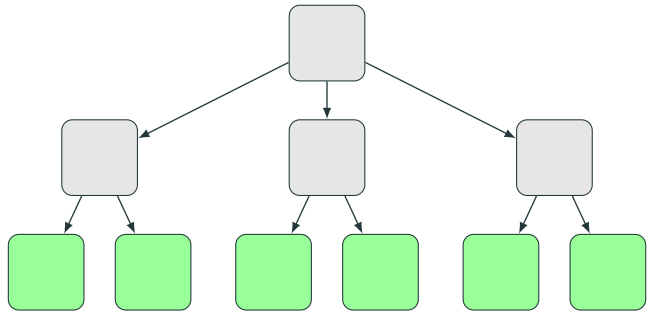
DPTree



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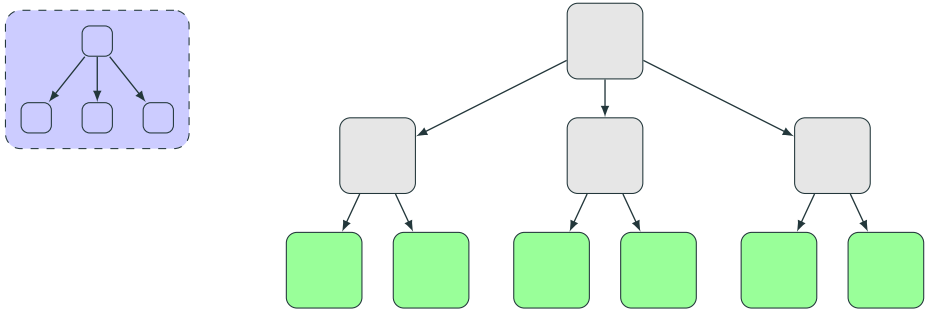

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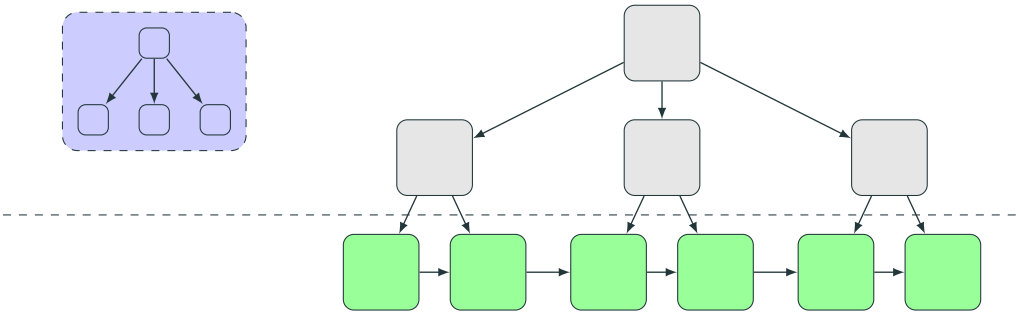

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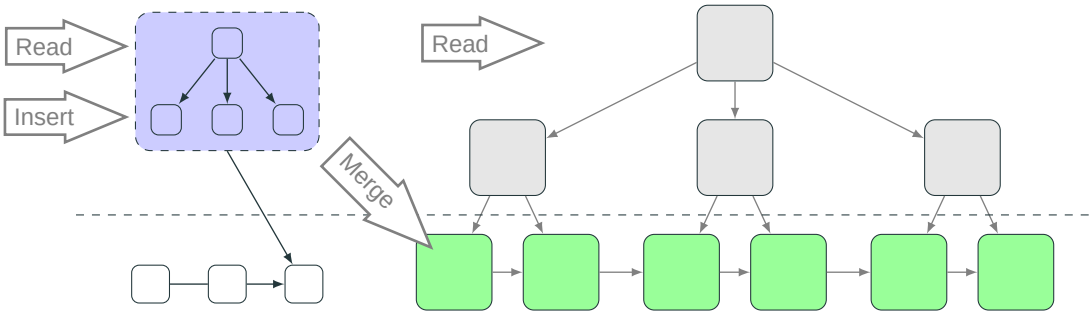

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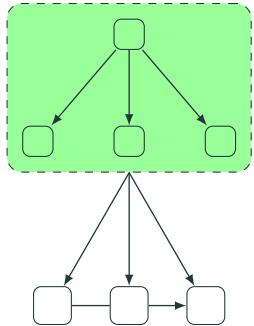
Learned Index



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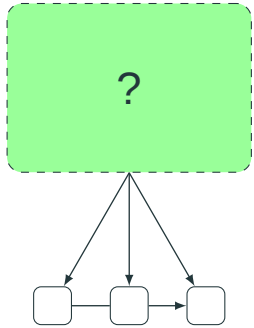
Learned Index



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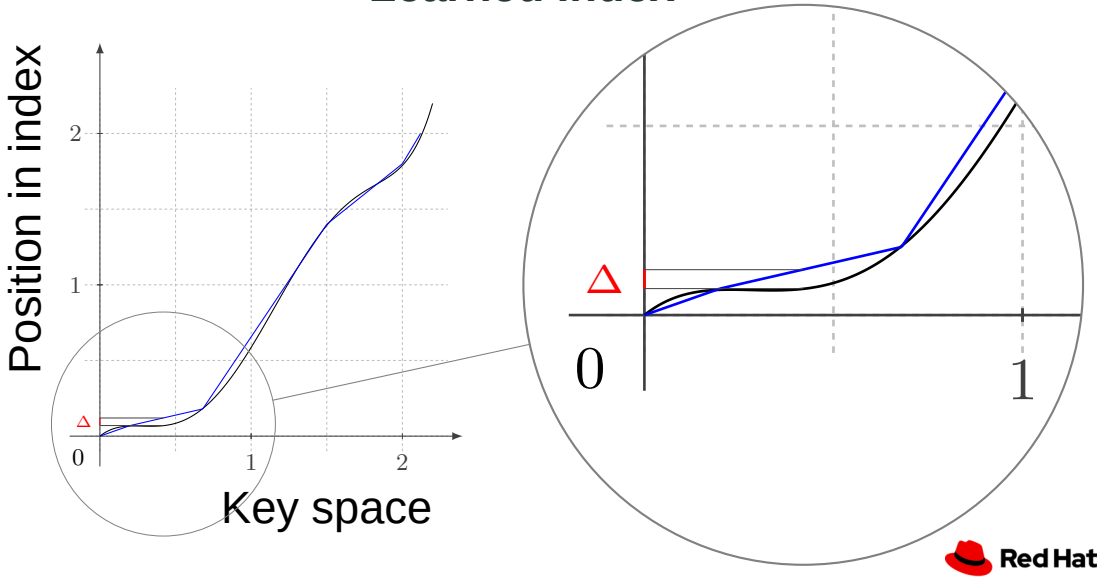

Is that all?

Red Hat

➔ Buffered (Lazy) B-Tree

- ➔ Buffered (Lazy) B-Tree
- ➔ Cache conscious B-Tree

- ➔ Buffered (Lazy) B-Tree
- ➔ Cache conscious B-Tree
- ➔ Distributed B-Tree

- ➔ Buffered (Lazy) B-Tree
- ➔ Cache conscious B-Tree
- ➔ Distributed B-Tree
- ➔ UB-Tree

- ➔ Buffered (Lazy) B-Tree
- ➔ Cache conscious B-Tree
- ➔ Distributed B-Tree
- ➔ UB-Tree
- ➔ Skip List

- ➔ Buffered (Lazy) B-Tree
- ➔ Cache conscious B-Tree
- ➔ Distributed B-Tree
- ➔ UB-Tree
- ➔ Skip List
- ➔ LSM Tree

- ➔ Buffered (Lazy) B-Tree
- ➔ Cache conscious B-Tree
- ➔ Distributed B-Tree
- ➔ UB-Tree
- ➔ Skip List
- ➔ LSM Tree
- ➔ Trie

- ➔ Buffered (Lazy) B-Tree
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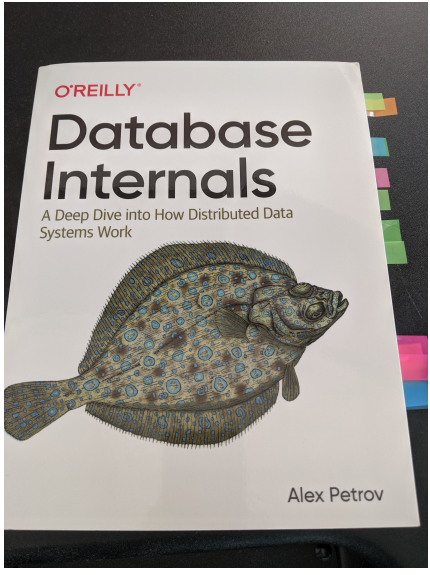
- ➔ Trie
- ➔ ...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