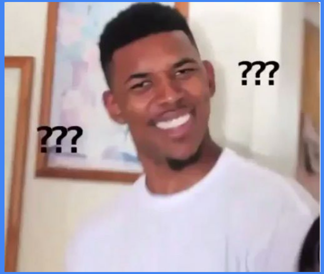
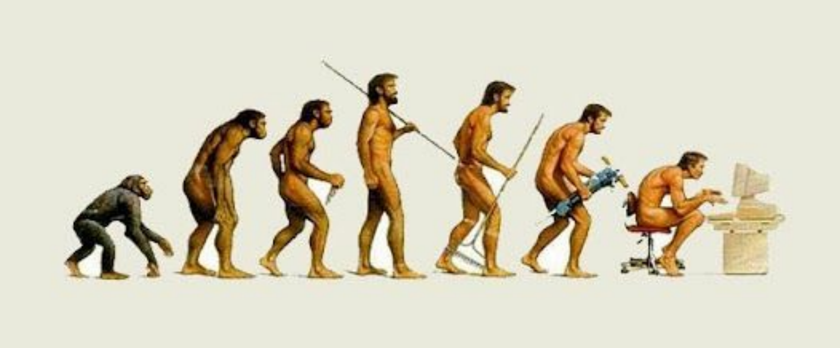
~~Adaptive~~ Adaptive Indexing



Team: Jiangshan Luo, Ruidong Duan

Background

In Nature



In Database System

Issues:

- Unknown Workloads / User Needs
- Large Amount of Raw Data
- Short Query Response Time
- etc.

How should we design a system to handle these issues?

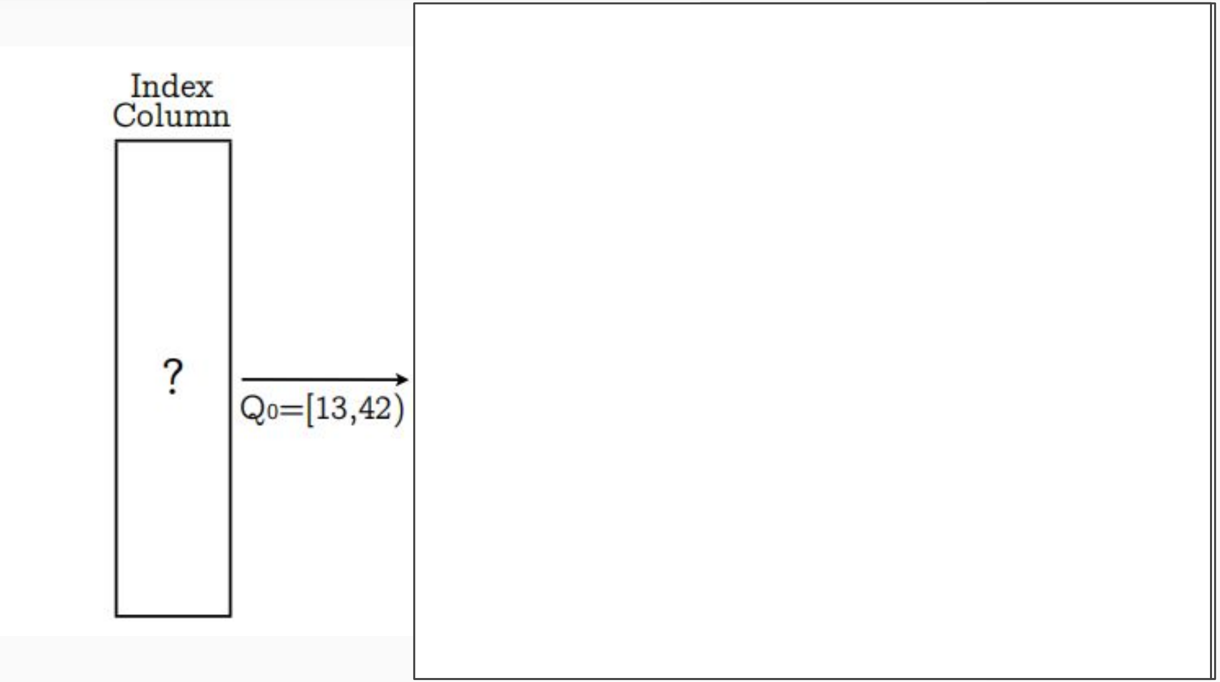
- Manually Design? (painful)

- Any other solution that make the system do it for us? - Yes! Adaptive Indexing Algorithm.

Instead of making decision in the first place,

how about organizing the system when we see the workload?

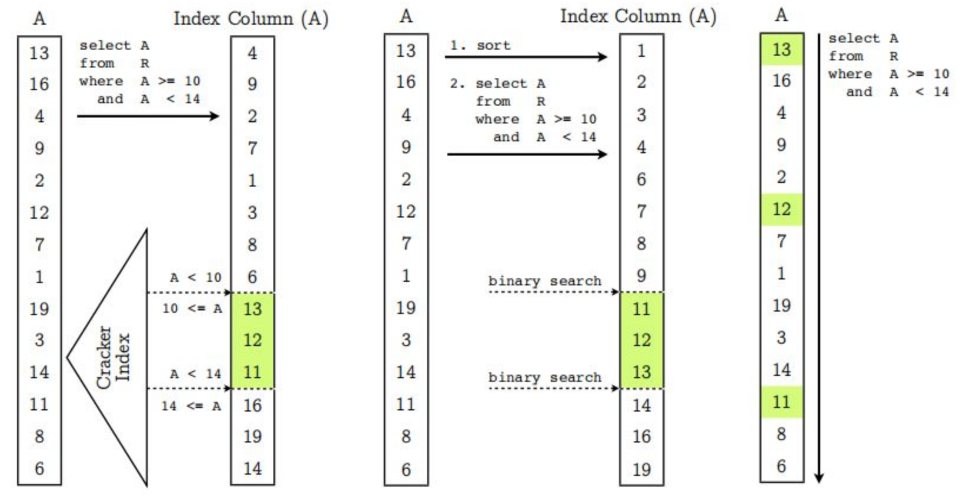
Example - Standard Cracking



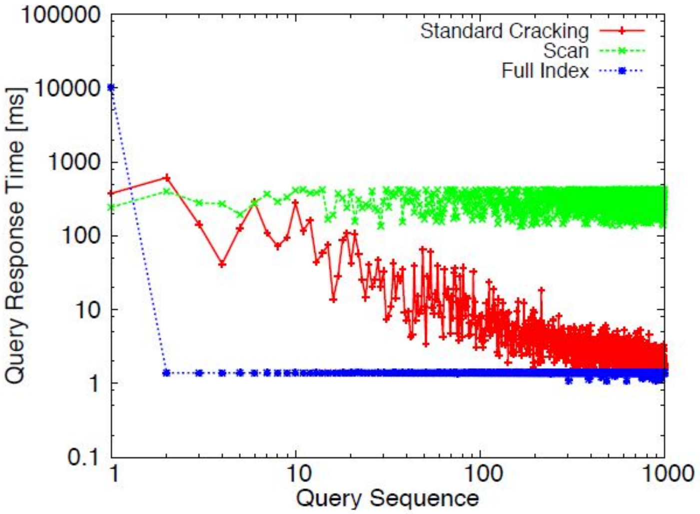
By Using Adaptive Indexing, Our System Is Allowed To:

- **Shift the cost of index maintenance** from Update to Query process
- **Reorganize data** based on workloads
- **Gradually construct index**
- **Continuously improve its performance** during queries

Performance



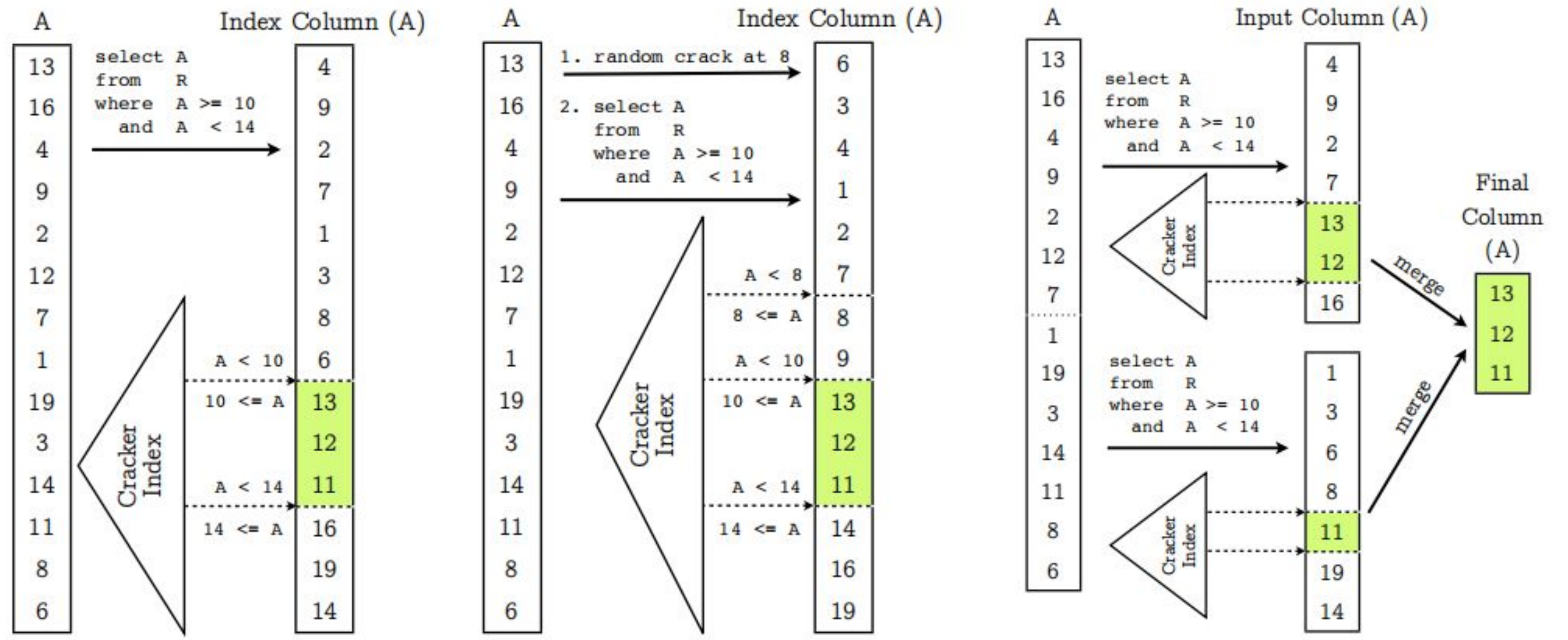
(a) Standard Cracking (DC) (d) **Sort + Binary Search**. (e) **Scan**.



(b) Reproducing Cracking Behaviour

However, it's NOT perfect..

- Slow convergence speed
- “Sensitive” to workloads and data distributions
- Existing methods are specialized for different needs



(a) Standard Cracking (**DC**) (b) Stochastic Cracking (**DD1R**) (c) Hybrid Cracking (**HCS**). For **HSS**, the inputs are sorted.

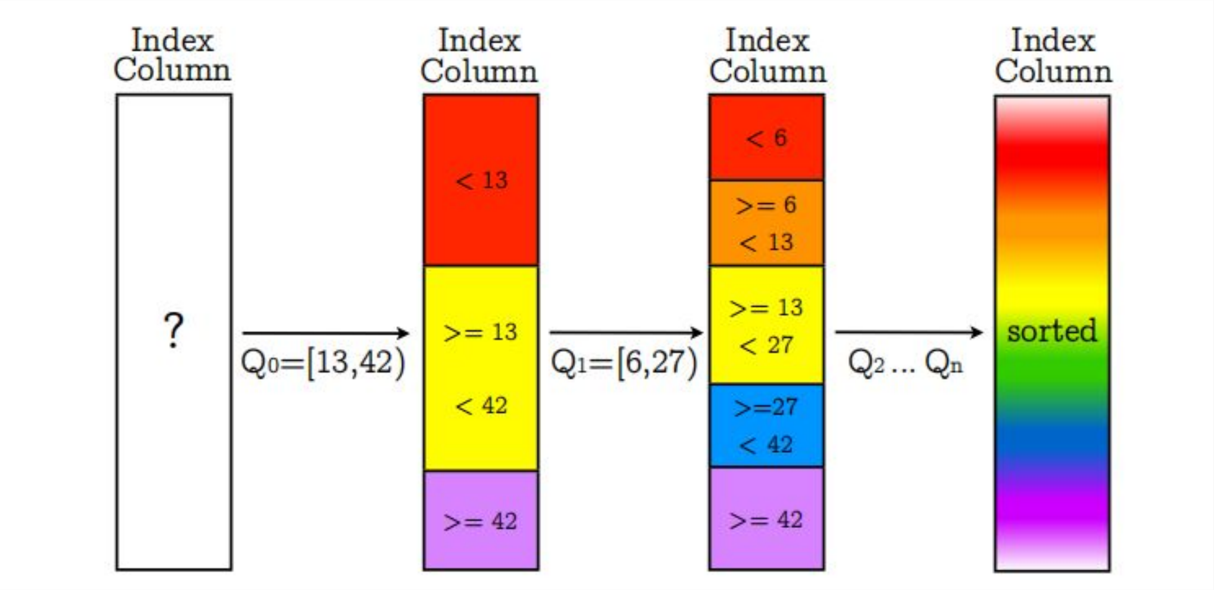
Well. How about being more "adaptive"?

Adaptive Adaptive Indexing (meta-adaptivity)

Adaptive Adaptive Indexing

- A generalized adaptive algorithm
- Consider the second higher level of adaptivity
- Adaptive itself to the characteristics of existing methods

1. Generalize Reorganization Method - Data Partitioning



two times partition-in-k (fan-out k = 2)

1. Generalize Reorganization Method - Data Partitioning

So, what if we are able to manage “k”?

- k = 2 with two times partition-in-k — **Standard Cracking**
- k = 2^n for n bits keys — **Sorted Data**

Change the system behavior to emulate any other existing algorithms.

2. Adapt Reorganization Effort (dynamic fan-out k)

- **Radix-based partitioning algorithm**
  - Put data into k “basket”
  - k = amount of radix bit
- **Process the first query and subsequent queries separately**
  - Out-of-place partitioning
  - In-place partitioning
  - Sort the data

2. Adapt Reorganization Effort (fan-out k)

optimizations

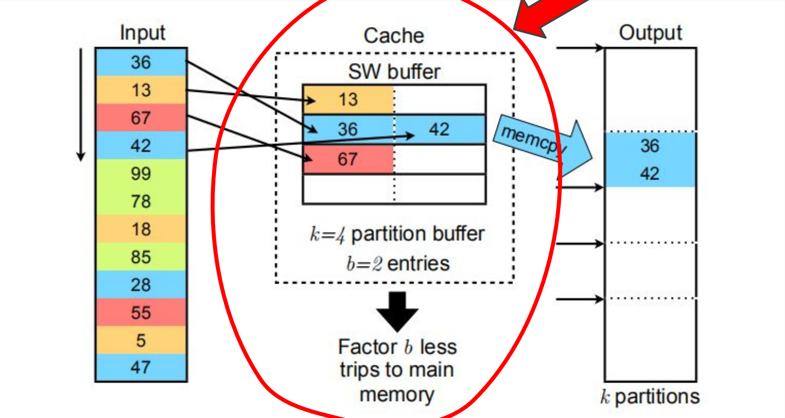


Fig. 3: ***Out-of-place partitioning*** *using* ***software managed buffers*** *[12].*

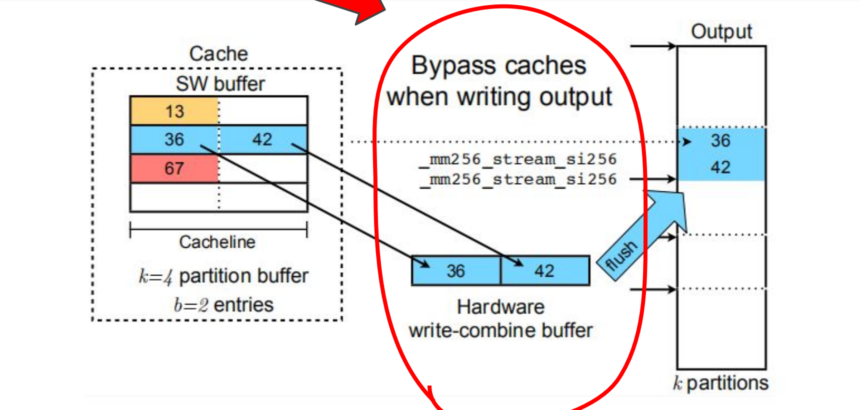
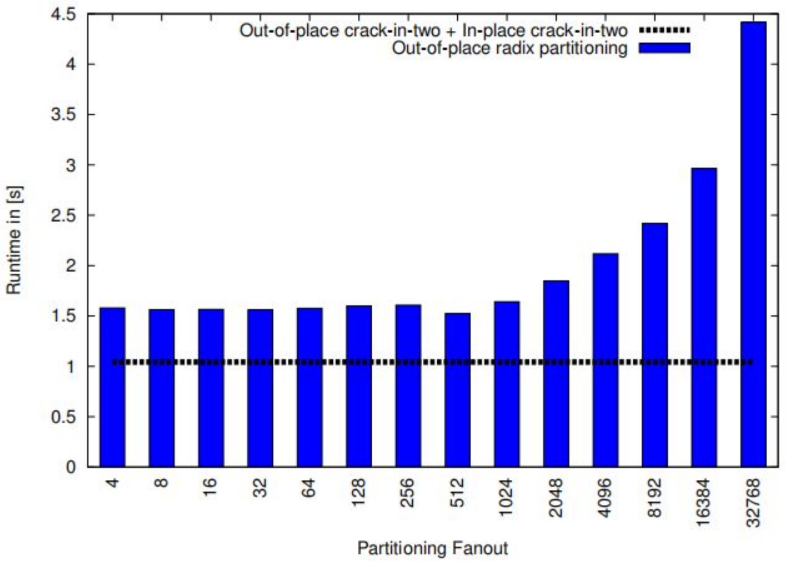
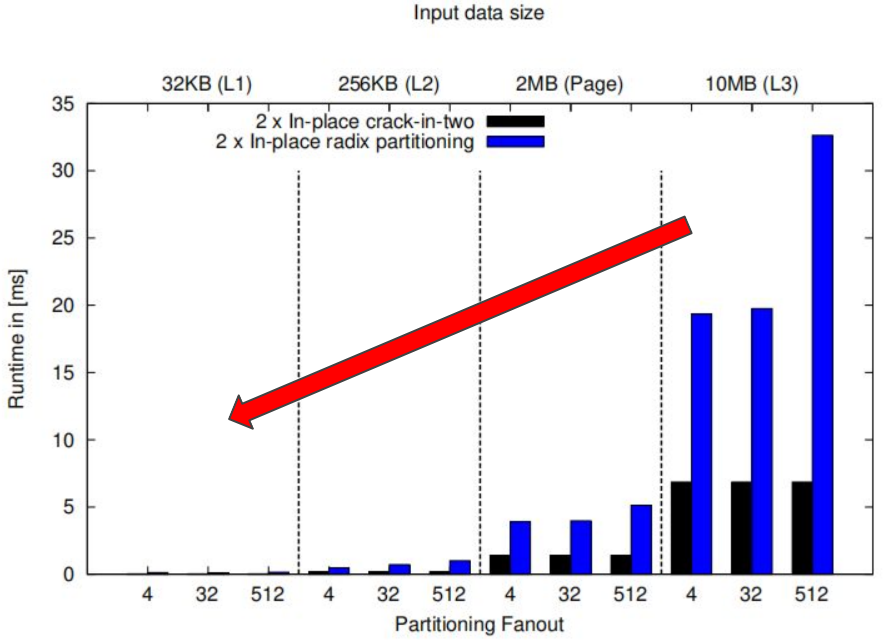


Fig. 4: *Enhancing* ***software managed buffers*** *using* ***non-temporal streaming stores*** *[12].*

Out-of-place partitioning

2. Adapt Reorganization Effort (fan-out k)





Performance

2. Adapt Reorganization Effort (fan-out k)

$$f(s,q) = \begin{cases} b_{first} & \text{if } q = 0 \\ b_{min} & \text{else if } s > t_{adapt} \\ b_{min} + \left\lceil (b_{max} - b_{min}) \cdot \left(1 - \frac{s}{t_{adapt}}\right) \right\rceil & \text{else if } s > t_{sort} \\ b_{sort} & \text{else.} \end{cases}$$

Parameter	**Meaning**
b_{first}	Number of fan-out bits in the very first query.
t_{adapt}	Threshold below which fan-out adaption starts.
b_{min}	Minimal number of fan-out bits during adaption.
b_{max}	Maximal number of fan-out bits during adaption.
t_{sort}	Threshold below which sorting is triggered.
b_{sort}	Number of fan-out bits required for sorting.
$skewtol$	Threshold for tolerance of skew.

2. Adapt Reorganization Effort (fan-out k)

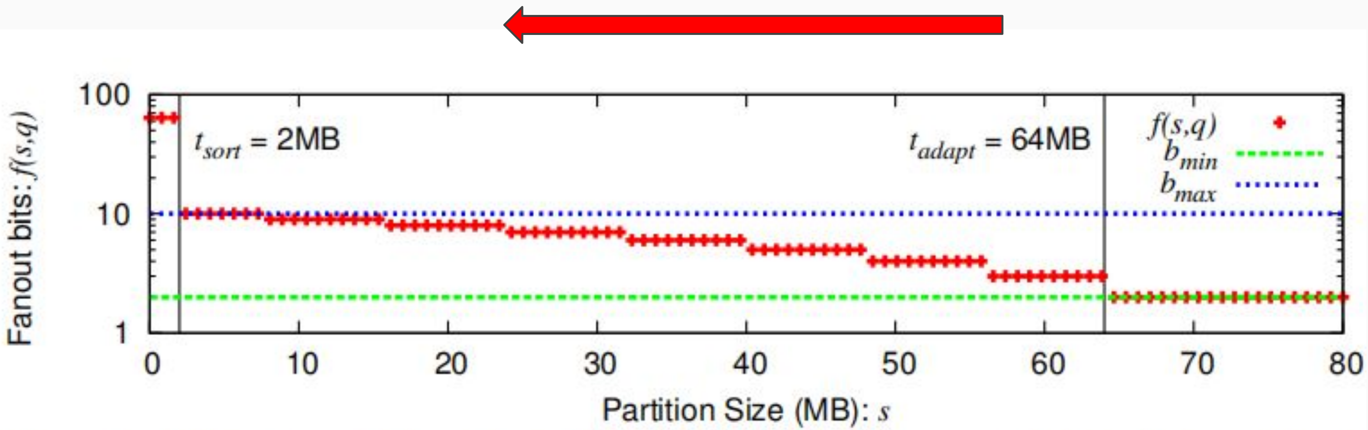
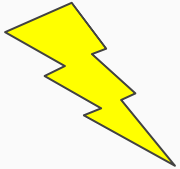


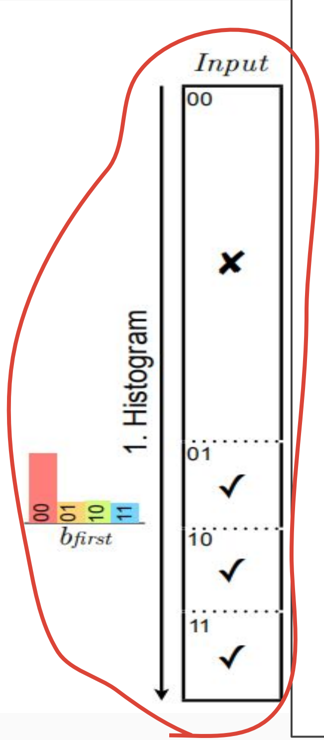
Fig. 5: The **partitioning fan-out bits** returned by $f(s, q)$ for partition sizes s from 0MB to 80MB and $q > 0$ with $t_{adapt} = 64MB$, $b_{min} = 2$, $b_{max} = 10$, $t_{sort} = 2MB$, and $b_{sort} = 64$.

3. Identify & Defuse Skewed Key Distributions

Not uniformly distributed



performance



Experimental Evaluation

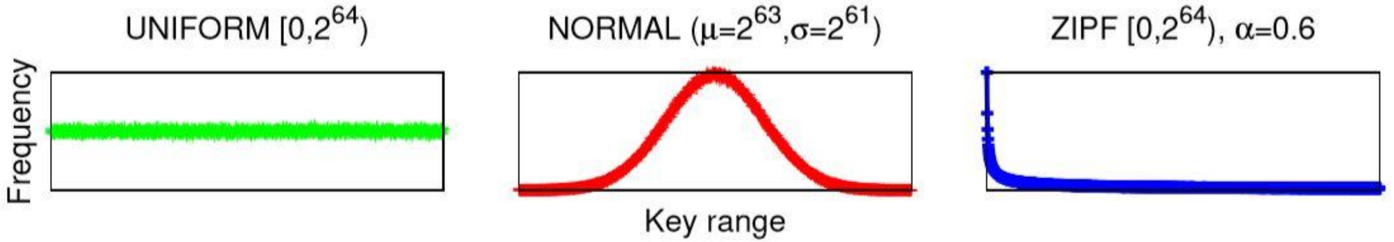


Fig. 8: Different ***key distributions*** *used in the experiments.*

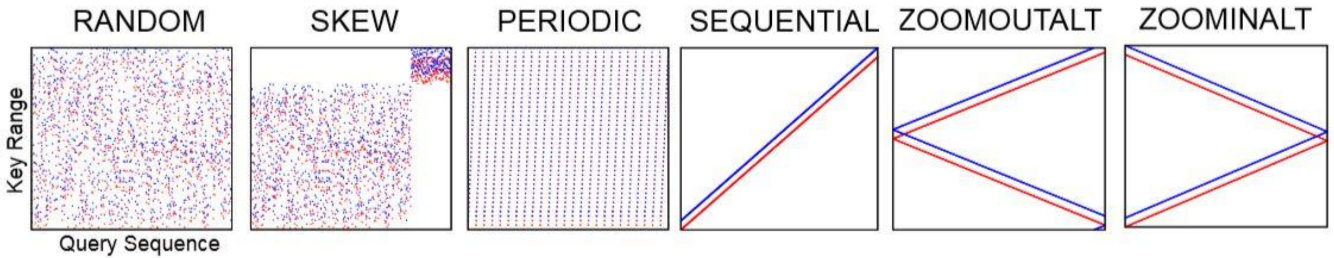


Fig. 9: Different ***query workloads****. Blue dots represent the* $high$ *keys whereas red dots represent the* low *keys.*

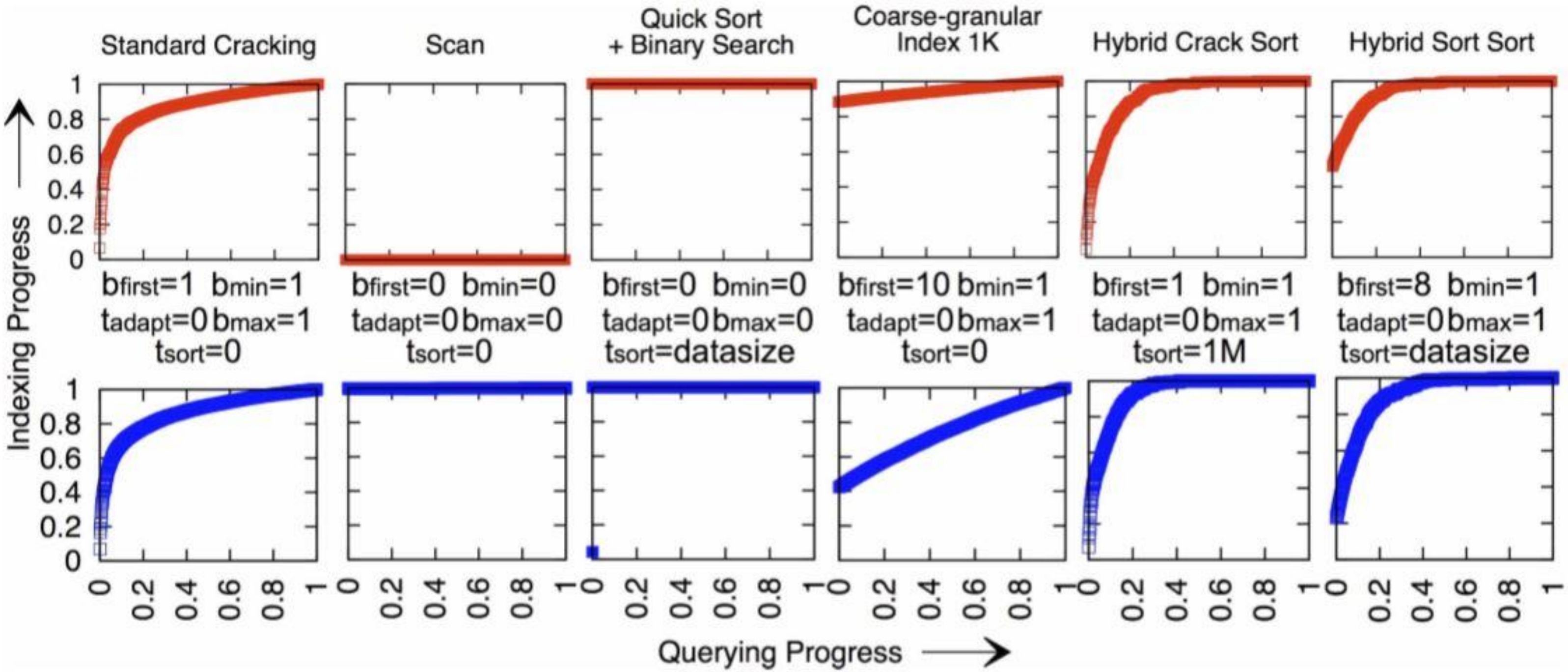
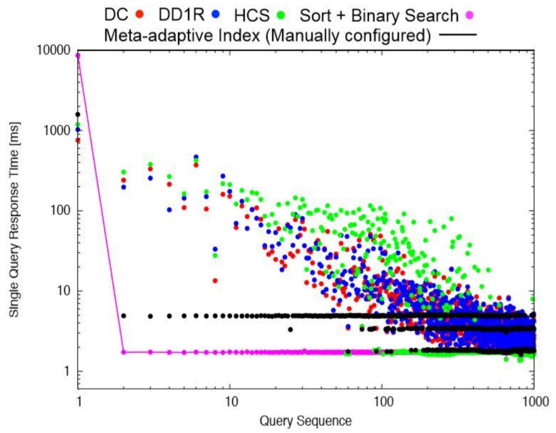
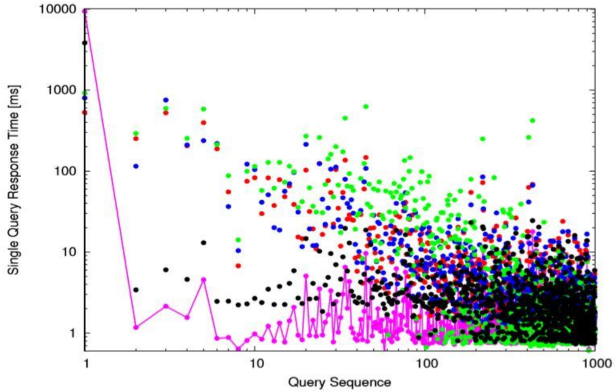


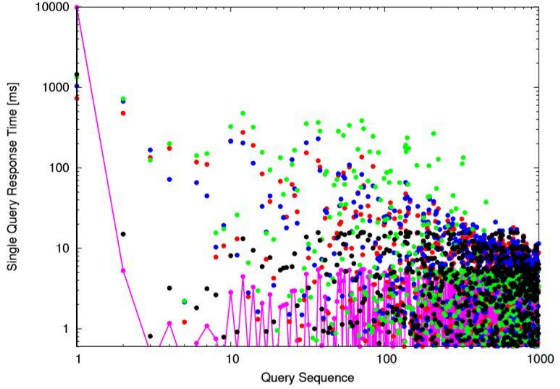
Fig. 10: **Emulation of adaptive indexes and traditional methods.** The top row shows the signatures of the baselines from [1] in red. The bottom row shows the signatures of the corresponding emulations of our meta-adaptive index in blue, alongside with the parameter configurations that were used.



(a) $\mathcal{U}(min = 0, max = 2^{64} - 1)$

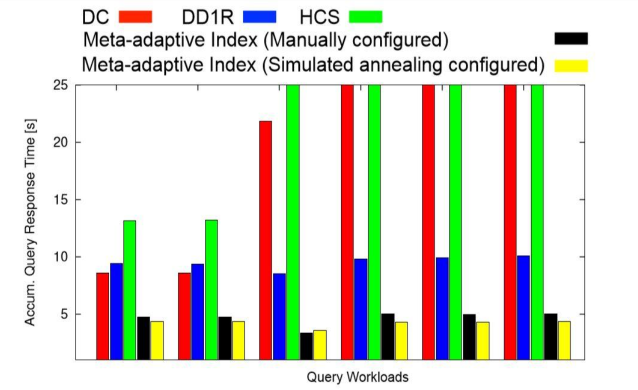


(c) $\mathcal{Z}(min = 0, max = 2^{64} - 1, \alpha = 0.6)$

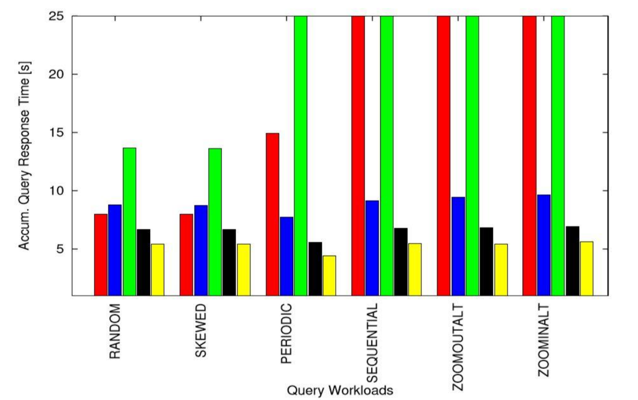


(b) $\mathcal{N}(\mu = 2^{63}, \sigma = 2^{61})$

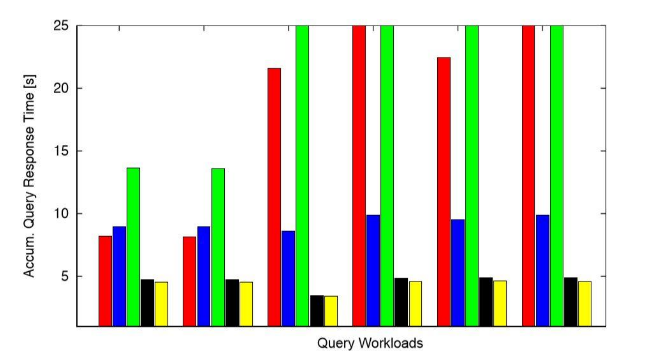
*Fig. 11: **Individual query response times** of the meta-adaptive index (configured according to Section VIII-C1) in comparison to baselines for a **uniform** (11(a)), **normal** (11(b)), and **Zipf-based** (11(c)) key distribution. The used query workload is RANDOM with 1% selectivity on the key range.*



(a) $\mathcal{U}(min = 0, max = 2^{64} - 1)$



(c) $\mathcal{Z}(min = 0, max = 2^{64} - 1, \alpha = 0.6)$

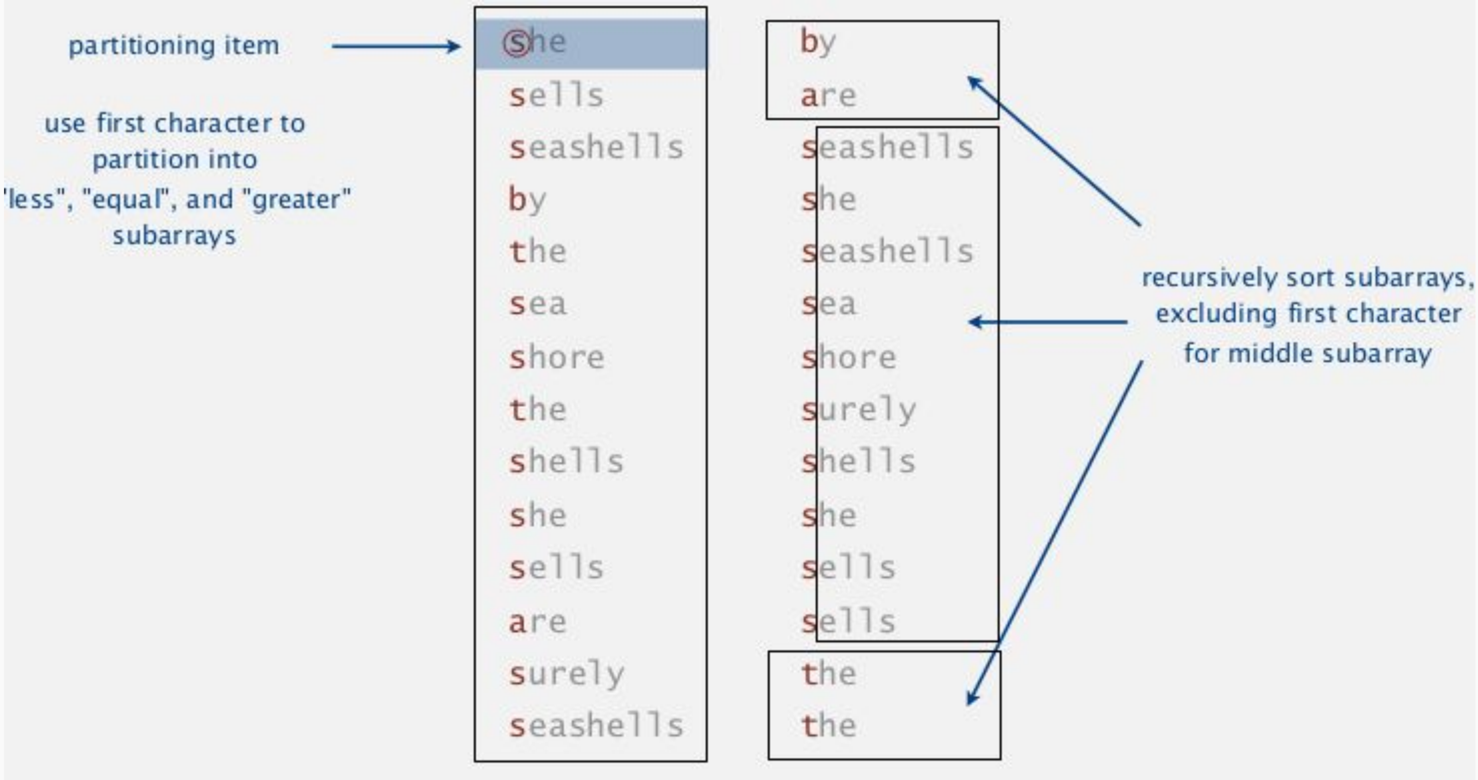


(b) $\mathcal{N}(\mu = 2^{63}, \sigma = 2^{61})$

Fig. 12: **Accumulated query response times** *of the meta-adaptive index both manually configured (Section VIII-C1) as well automatically configured using simulated annealing (Section VIII-D1) under* **uniform** *(12(a)),* **normal** *(12(b)), and* **Zipf-based** *(12(c)) key distributions and* **different query workloads** *(see Section VIII-A).*

Experimental Evaluation

Appendix


partitioning item
use first character to partition into "less", "equal", and "greater" subarrays
she
sells
seashells
by
the
sea
shore
the
shells
she
sells
are
surely
seashells
by
are
seashells
she
seashells
sea
shore
surely
shells
she
sells
sells
the
the
recursively sort subarrays, excluding first character for middle subarray

Review

Innovative idea

Perfect substitute

Details in manual configuration

Other automatic configuration method