Too Many Knobs to Tune? Towards Faster Database Tuning by Pre-selecting Important Knobs

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Database tuning is important!

Realizing *high performance* requires finding optimal values for configuration knobs

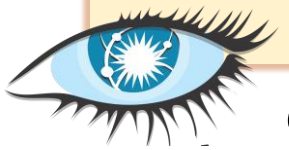
```
...
commitlog_sync_period_in_ms: 10000
commitlog_segment_size_in_mb: 32
compaction_throughput_mb_per_sec: 16
concurrent_reads: 32
concurrent_writes: 32
memtable_heap_space_in_mb: 2048
memtable_cleanup_threshold: 0.33
native_transport_max_threads: 128
```

Cassandra Default Configuration

Tuning

Process

```
...
commitlog_sync_period_in_ms: 50000
commitlog_segment_size_in_mb: 128
compaction_throughput_mb_per_sec: 16
concurrent_reads: 128
concurrent_writes: 64
memtable_heap_space_in_mb: 1024
memtable_cleanup_threshold: 0.85
native_transport_max_threads: 256
```



Cassandra Tuned Configuration

Properly tuned database systems can achieve **2-3x** *higher* throughput (or *lower* 99-tile latency) compared to *default* configuration (PostgreSQL) [1]

[1] Dana Van Aken et. al. *Automatic Database Management System Tuning Through Large-scale Machine Learning*. (SIGMOD '17)

… but it's hard …

- 100s knobs in a typical system
- Most knobs take *continuous* values
- Unknown interactions among knobs
- Evaluating a single configuration is expensive

```
...
commitlog_sync_period_in_ms: 50000
commitlog_segment_size_in_mb: 128
compaction_throughput_mb_per_sec: 16
concurrent_reads: 128
concurrent_writes: 64
memtable_heap_space_in_mb: 1024
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native_transport_max_threads: 256
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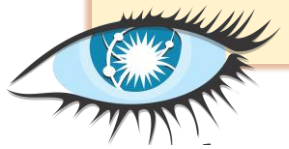


Cassandra configuration

Earlier tuning efforts relied on experience from human experts

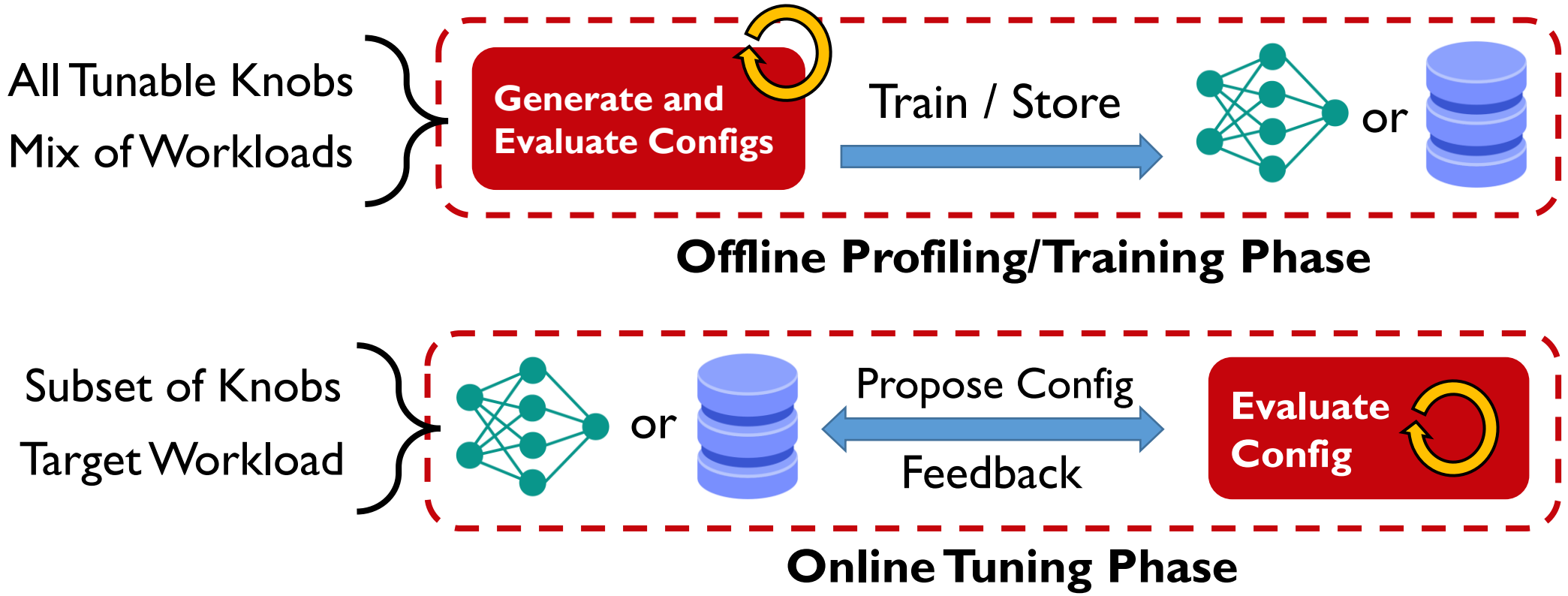
Recently proposed tuning frameworks can automate the procedure

Can achieve same (or even better) performance compared to manual tuning [2]

[2] Zhang, Ji, et al. *An end-to-end automatic cloud database tuning system using deep reinforcement learning* (SIGMOD'19)

Automated database tuning

Most existing auto-tuning database frameworks consist of (a) initial **offline** *profiling* phase and (b) an online *tuning* phase



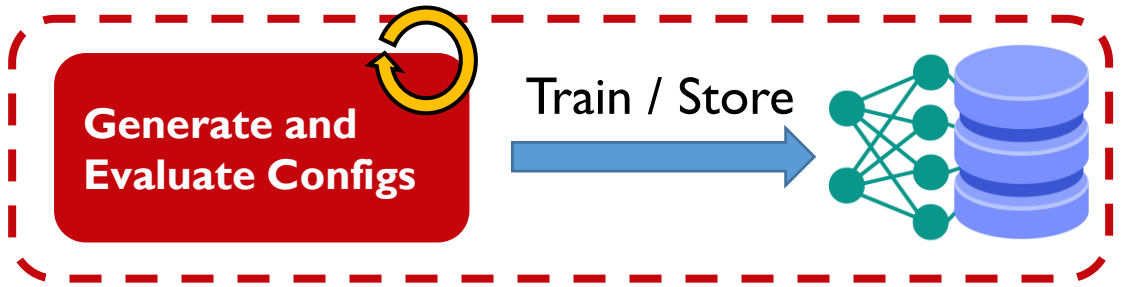
Motivation

Offline profiling is vital for the quality of proposed configurations

Yet, this phase may account for **>95%** of the *entire* tuning time

All Tunable Knobs ?

Mix of Workloads ?



Offline Profiling/Training Phase

How many knobs do we need to achieve "*good*" performance?

Can we *exploit* this to accelerate the offline phase?

Experimental study

How many knobs do we need to achieve "*good*" performance?

Cassandra
YCSB-A
5 out 155!

Do similar results hold for *different* workloads?

Cassandra
YCSB-B
Same 5 knobs!

Do similar results hold for a *different* database system?

PostgreSQL
YCSB-A, YCSB-B
Yes!

Outline

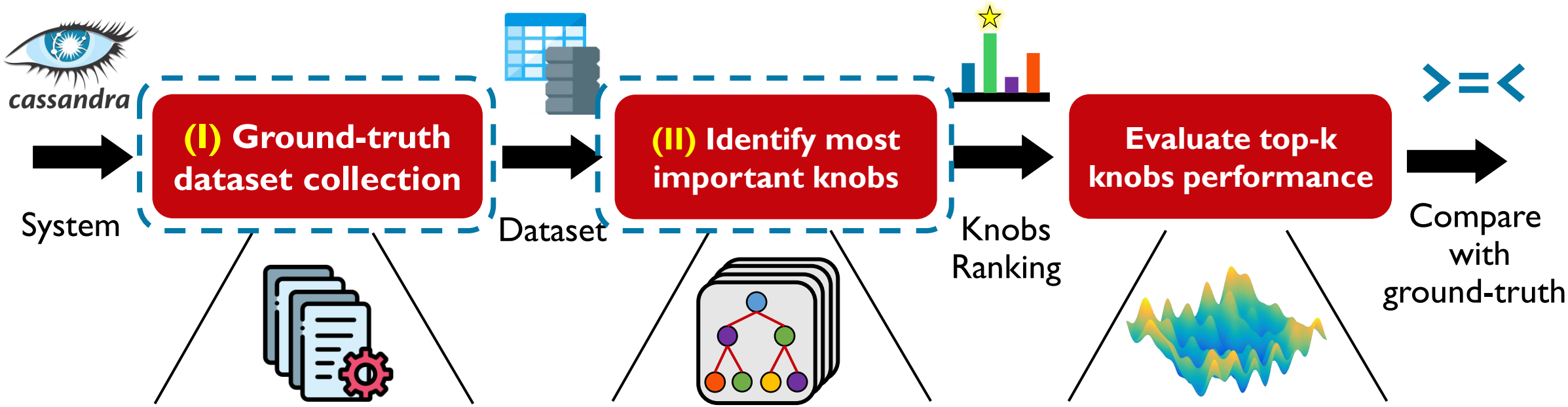
Background & Motivation

Methodology

Results

Towards Faster Database Tuning

Methodology



Generate and evaluate configuration samples (many knobs)

Identify relationship of each knob with system performance

Generate samples and find one with best perf. (top-k knobs)

(I) Generate and collect configuration samples

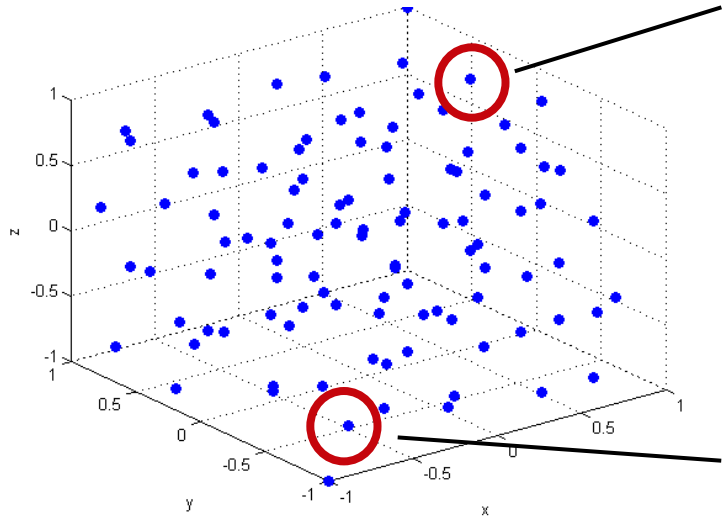
Intractable configuration space – limited number of samples

Latin Hypercube Sampling (LHS)

- Uniformly and thoroughly cover configuration space
- Employed by multiple existing systems

Number of Samples

Knobs / Range of values




```
{
commitlog_sync_period: 10 ms
concurrent_writes: 8
memtable_cleanup_threshold: 0.2
}
```

```
{
commitlog_sync_period: 5 ms
concurrent_writes: 64
memtable_cleanup_threshold: 0.8
}
```

(II) Identify Important Knobs

Knobs values (features)

Performance (outcome)

```
{
commitlog_sync_period: 10 secs
concurrent_writes: 8
memtable_cleanup_threshold: 0.2
}
```

```
{
commitlog_sync_period: 5 secs
concurrent_writes: 64
memtable_cleanup_threshold: 0.8
}
```

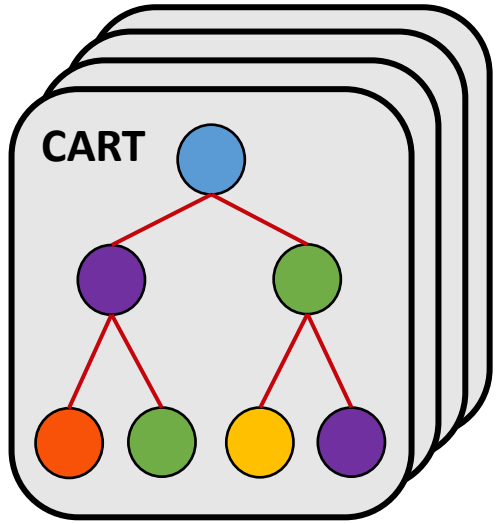
```
{
commitlog_sync_period: 2 secs
concurrent_writes: 24
memtable_cleanup_threshold: 0.5
}
```

• • •

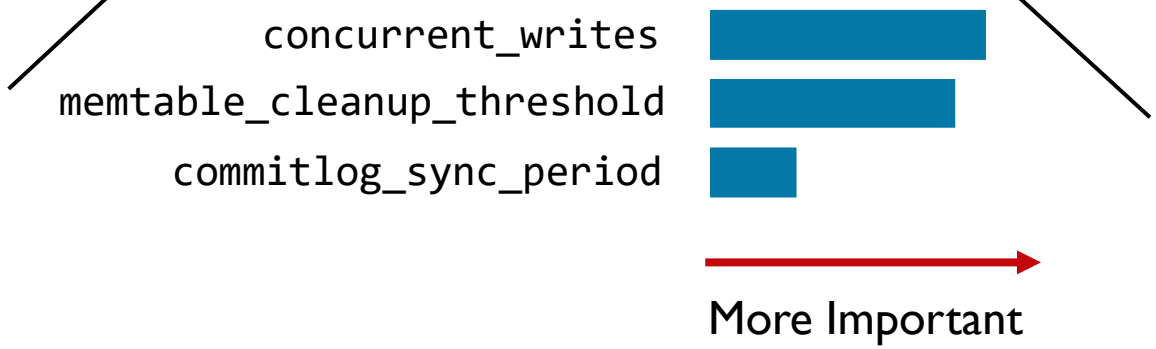
Train Regression

Model

Random Forest



Knob Relative Importance Ranking



Experimental Setup

Machine hardware

- Intel Xeon Silver 4114 CPU, 64 GB RAM, 480GB SSD, Ubuntu 18.04
- Employ 30 identical machines to parallelize the evaluation process (CloudLab)

Ground-truth sample collection

- Apache Cassandra v3.11, PostgreSQL v9.6
- YCSB-A (50% read/50% write), YCSB-B (95% read/5% write)
- 25,000 samples with LHS – tweaking ~30 knobs for both systems
- Each sample takes ~9 minutes to evaluate

PostgreSQL

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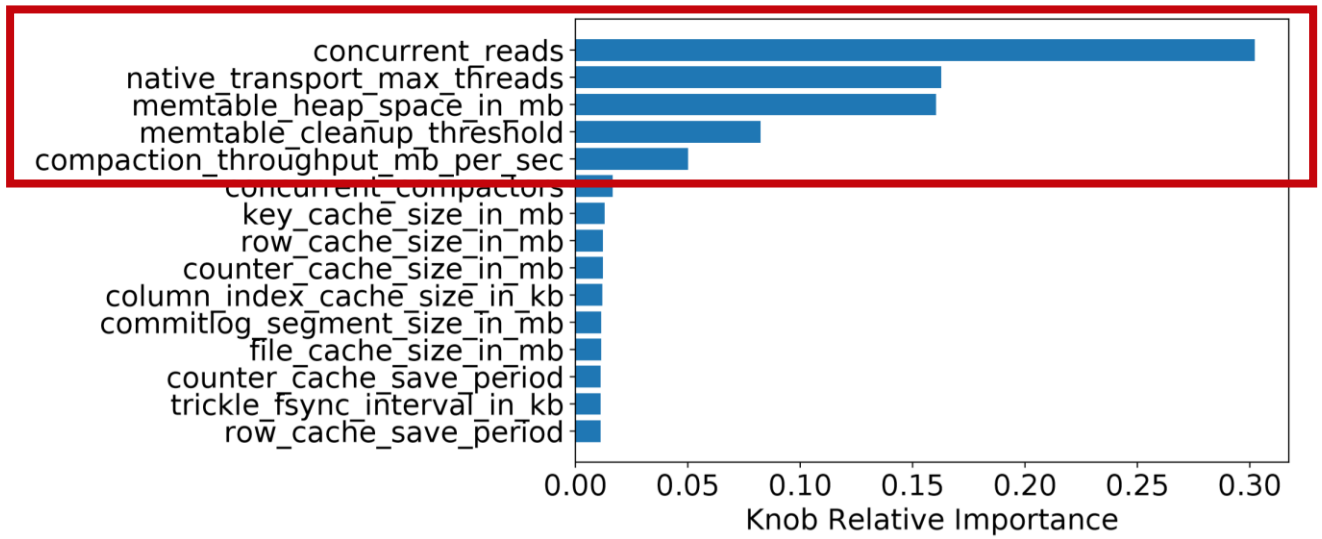
How many knobs matter?

Apache Cassandra – YCSB-A



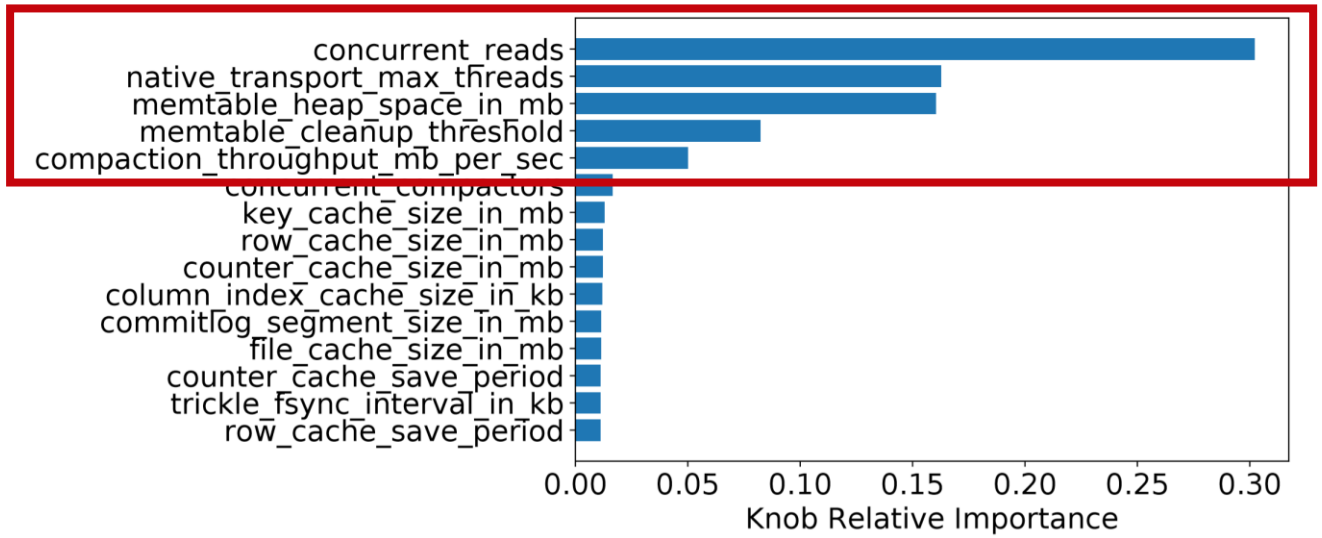
According to the ML model, these **5** knobs have the most impact on system performance

Most important knobs

- `concurrent_reads`: number of concurrent read operations
- `native_transport_max_threads`: number of threads used to handle requests
- memory table–related knobs: size of memtable, when to flush to disk

…but how much *performance* can we achieve?

Apache Cassandra – YCSB-A

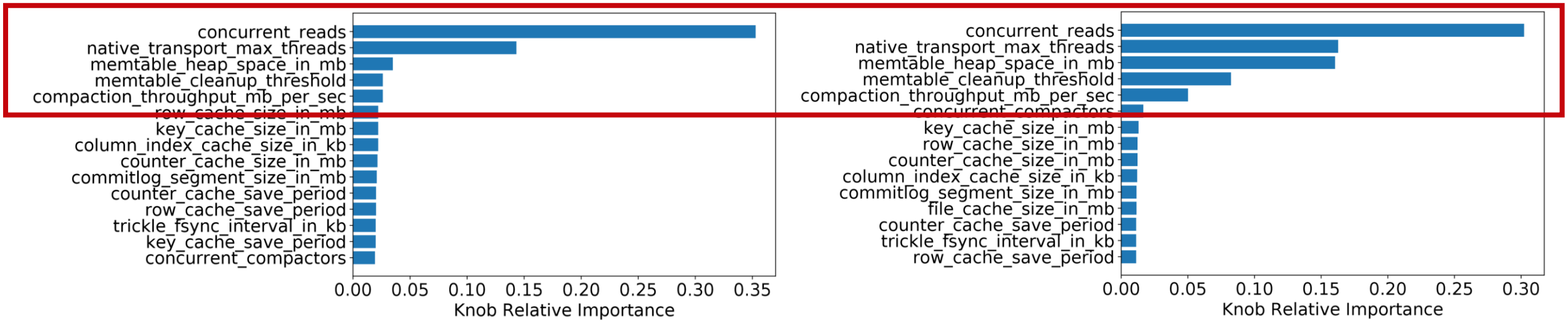


Tuning just a few *important* knobs can still yield *high* performance!

Best Configuration Performance	Throughput (ops/sec)	Read Latency (micro-seconds)	Write Latency (micro-seconds)
Tuning 30 knobs	74780.33	744.34	302.82
Tuning 5 knobs	74304.42	750.56	308.08
% of tuning 30 knobs	**99.36%**	**100.84%**	**101.41%**

What about a different workload?

Apache Cassandra – YCSB-B



YCSB-B (95%/5% r/w)

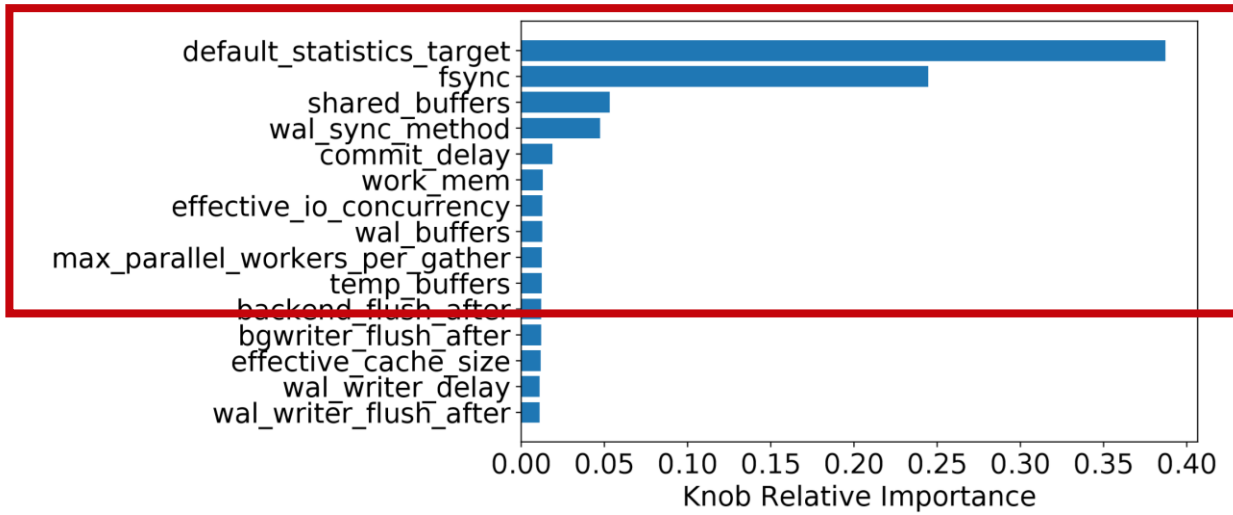
YCSB-A (50%/50% r/w)

#1: A handful of knobs affect the performance for YCSB-B

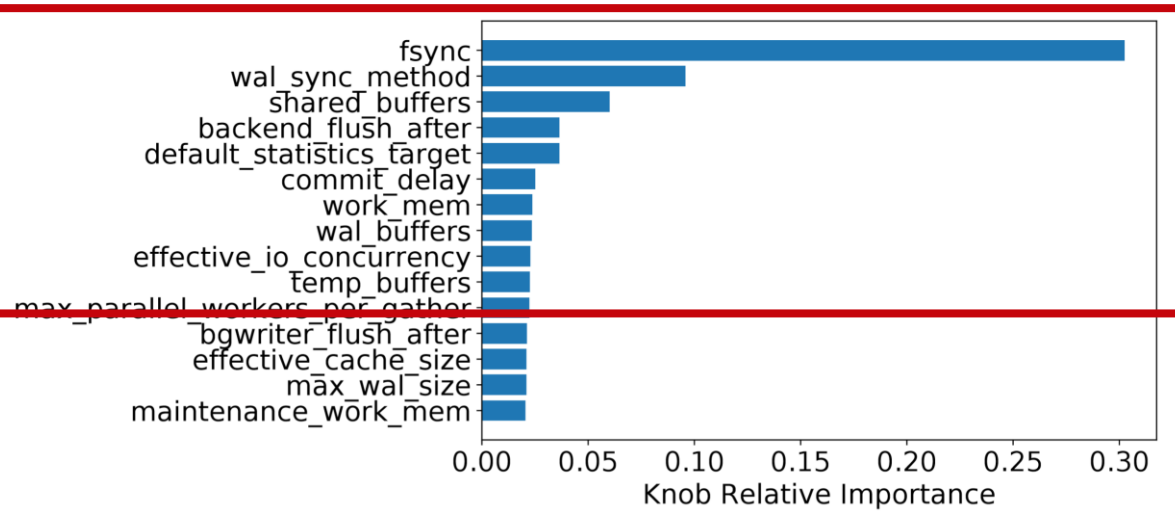
#2: **Overlap** of important knobs across the two workloads

What about a different database system?

PostgreSQL – YCSB-A, YCSB-B



YCSB-A (50%/50% r/w)



YCSB-B (95%/5% r/w)

In general, we observe similar results for PostgreSQL

Knob importance ranking more *diverse* between the workloads

… still top-8 knobs are *almost* identical

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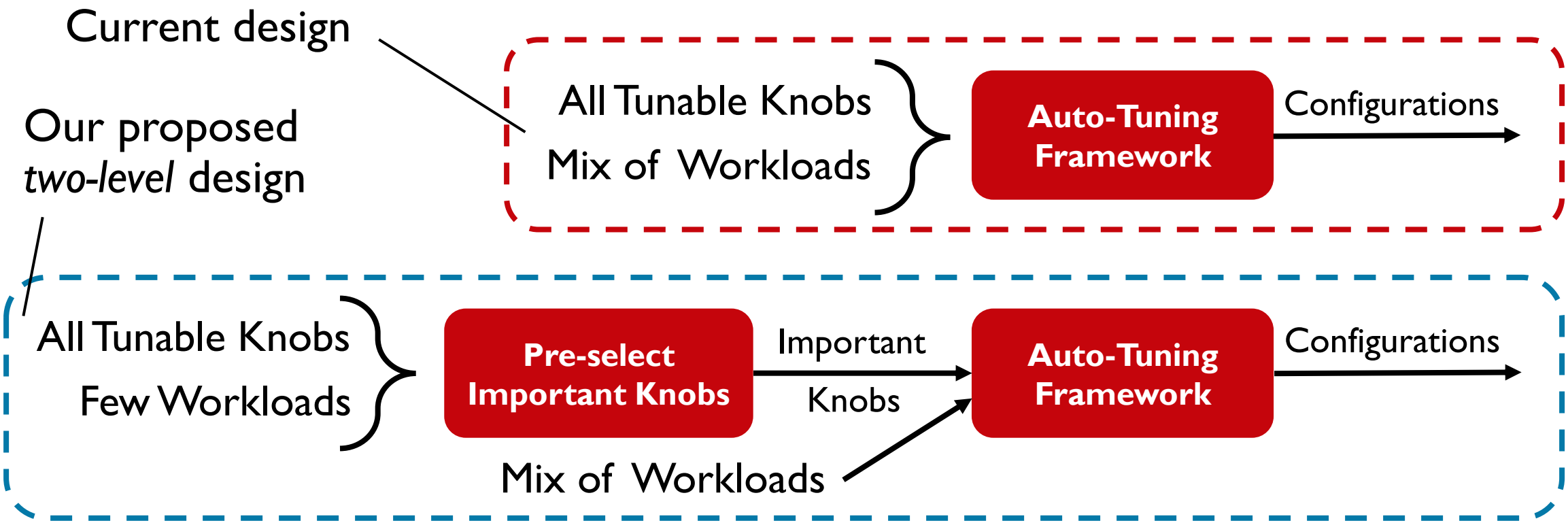
Pre-selecting Important Knobs

Utilize the ML model to identify important knobs before running the tuner

Reduces configuration search space size / training dataset of tuners



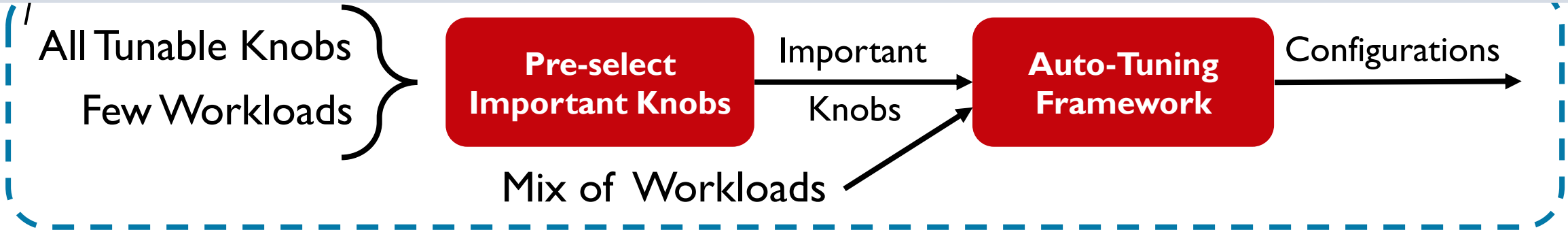
Pre-selecting Important Knobs

Utilize the ML model to identify important knobs before running the tuner

Early results with an existing tuner, *BestConfig*.

When tuning top-5 knobs the best performance is reached with 5x *fewer* iterations compared to tuning 30 knobs

(Apache Cassandra, YCSB-A)



Discussion

Can we make the *pre-selection* step cheaper? (25,000 samples)

- With our ML-based method ~400 samples are needed (early results)
- Can we use some other (cheaper) method? (evaluate *few* workloads?)

How does the hardware affect the important knobs?

- Can we avoid (or minimize) tuner adaptation time to new hardware?

Can we account for system reliability when tuning?

- Existing tuners may *sacrifice* reliability for performance
- `fsync` / recovery-related flags / checkpointing settings

Summary

Tuning with few *important* knobs can yield high performance

- Trend seems to hold across different workloads and systems
- Significant overlap of top knobs across different workloads

Proposed an initial design to accelerate database auto-tuners

- Pre-selecting important knobs *reduces* configuration search space
- Exploit top knobs similarity across workloads to make it faster?

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Thank you! Questions?

Reach me at kkanellis@cs.wisc.edu