Carver: Finding Important Parameters for Storage System Tuning

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Outline

- **Motivation**
- Background
- Design of Carver
- Evaluation
- Related Work
- Conclusions & Future Work

Motivation

- Tuning storage system parameters can provide significant gains
  - Default settings are often sub-optimal
- Storage system parameter space is huge
- Manual tuning vs. auto-tuning

Motivation (cont.)

- More challenges to solve
  - "Curse of dimensionality"
  - Tuning efficiency is critical for storage systems
- Storage parameters come with different "importance"
- **Parameter selection is a critical part of auto-tuning systems**

Carver Overview

- Measurement for storage parameter importance
- Sampling method
  - Pick a small subset of configurations
- Parameter selection algorithm

Key Contributions

- Quantitative analysis of importance of storage parameters on system performance
- Carver can pick important parameters efficiently
- Evaluated Carver on various datasets
  - Carver can find a near-optimal subset of important parameters in all cases

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Concepts

- Storage system
  - File system, underlying storage hardware and any layers between them
- Parameters
  - Configurable options
  - *E.g., block size*
- Parameter values
  - *E.g., 1K, 2K, 4K* (Ext4 block size)
- Configuration
  - Combination of parameter values
  - *E.g., [Ext4, 4K, data=ordered]*
- Parameter space
  - All possible configurations

Challenges

- Large parameter space
  - Ext4: 59 parameters, 10^{37} configs
  - Distributed, large-scale
- Evaluation is time-consuming
- Nontransferable tuning results
  - Hardware, workload, etc.
- Discrete and non-numeric
  - Linux I/O scheduler: noop, cfq, deadline

Dimensionality Reduction

- Feature extraction ✗
  - Project high-dimensional data into low-dimensional spaces
  - Constructed features
  - Lose physical meaning of original features
- Feature selection
  - Directly selects a subset of features from the original ones
  - Relationship between parameters
  - **Impact of parameters on target variable**
    - Throughput

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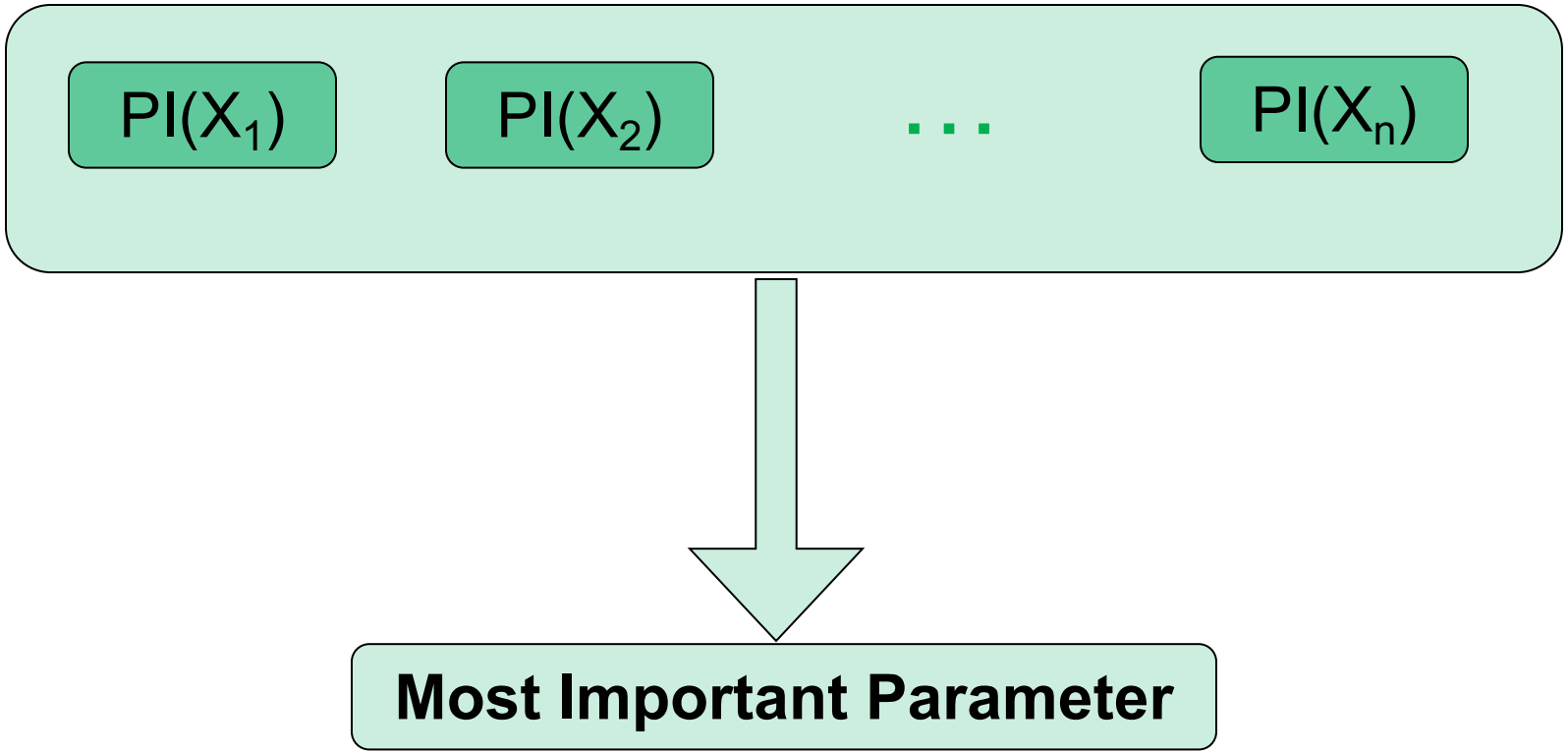
Carver: Measuring Parameter Importance

- Categorical parameters & continuous target variable
- Parameter Importance
  - Reduction in variance
- Conditional parameter importance
  - CPI(P_2 | P_1 = p)
  - E.g., given P_1 is fixed to “p”, find importance of P_2

Carver: Sampling

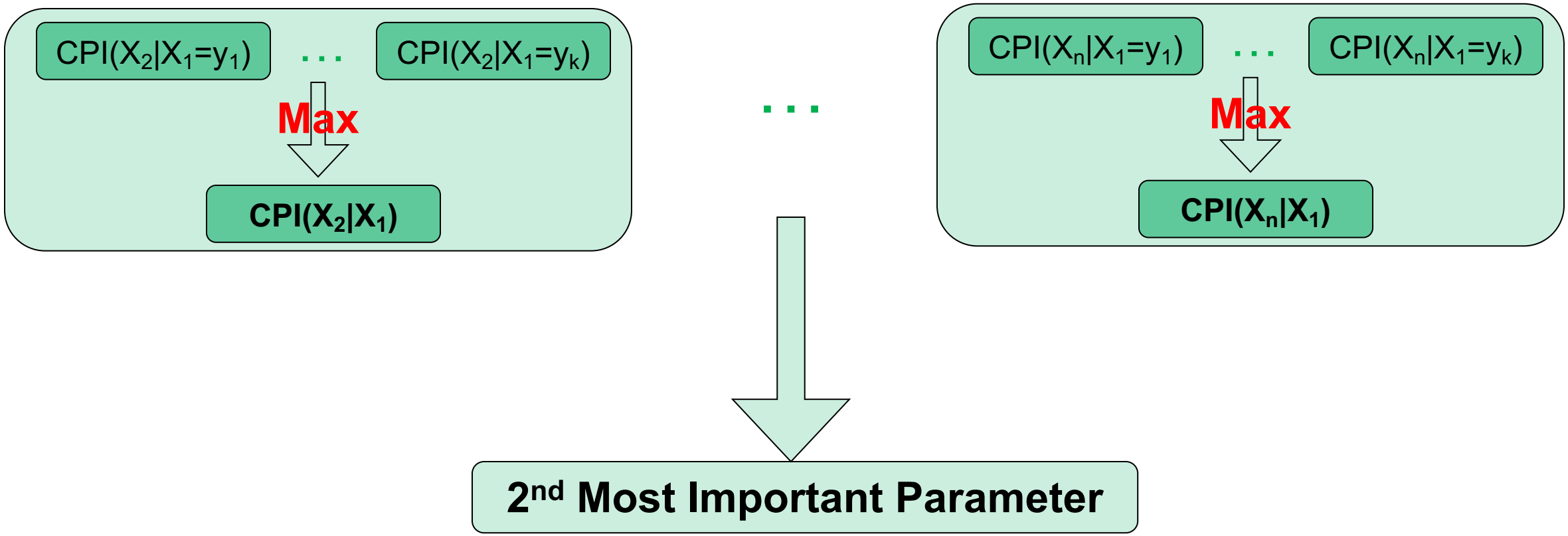
- Limit the number of evaluations
  - Evaluation of storage configurations is costly
- Sampling
  - Latin Hypercube Sampling
    - Latin square: one sample in each row and each column
    - Generalization to higher dimensions
    - Proved useful in system analysis

Carver: Parameter Selection (1)



Carver: Parameter Selection (2)

(Assume X_1 is as most important parameter.)



Carver: Parameter Selection (3)

- Repeat the process until stopping criterion is met
- Example stopping criteria:
  - Certain number of parameters have been selected
  - Variance within subsets of configurations (fixing values of selected parameters) falls below a certain threshold.

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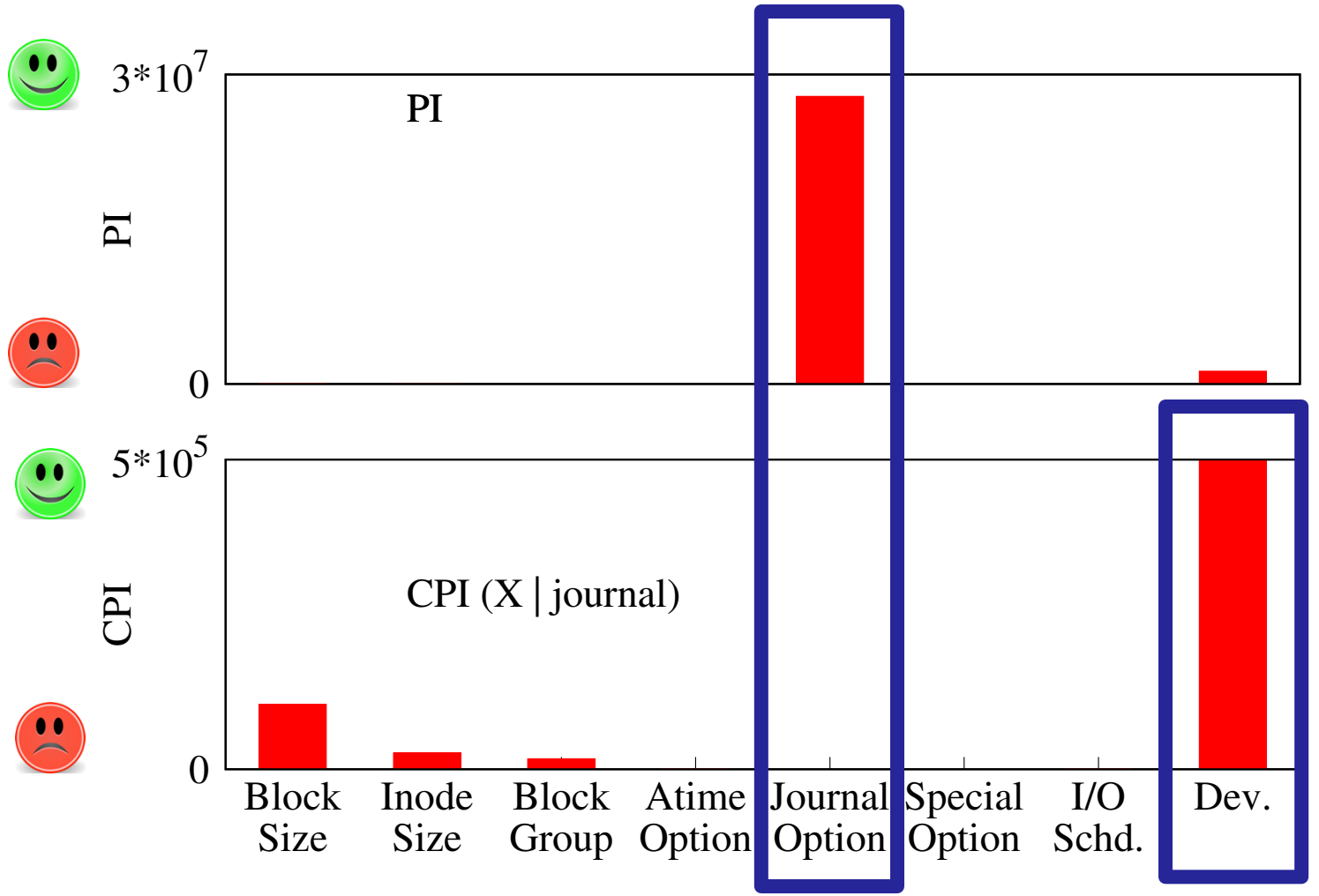
Evaluation: Testbed

- Hardware
  - Intel Xeon quad-core 2.4GHz CPU, 24G RAM, 4 drives (SAS-HDD 500GB, SAS-HDD 146GB, 1 SATA-HDD, SSD)
- Filebench
  - Workloads: fileserver, mailserver, webserver, dbserver
- Two Settings:
  - **S1**: *default working set size*
  - **S2**: *4G RAM, 10G working set size*

Evaluation: Settings

- Parameters spaces
  - 7 file system types, 4 workloads
  - inode size, block size, block group, journal options, mount options, special options, I/O scheduler, etc.
- Methodology
  - Pre-collect benchmark results for all configurations
    - 3+ runs for each configuration
    - **500,000 data points**
  - Evaluate Carver on collected datasets

Evaluation: Parameter Importance



Ext4, S1, Fileserver-default

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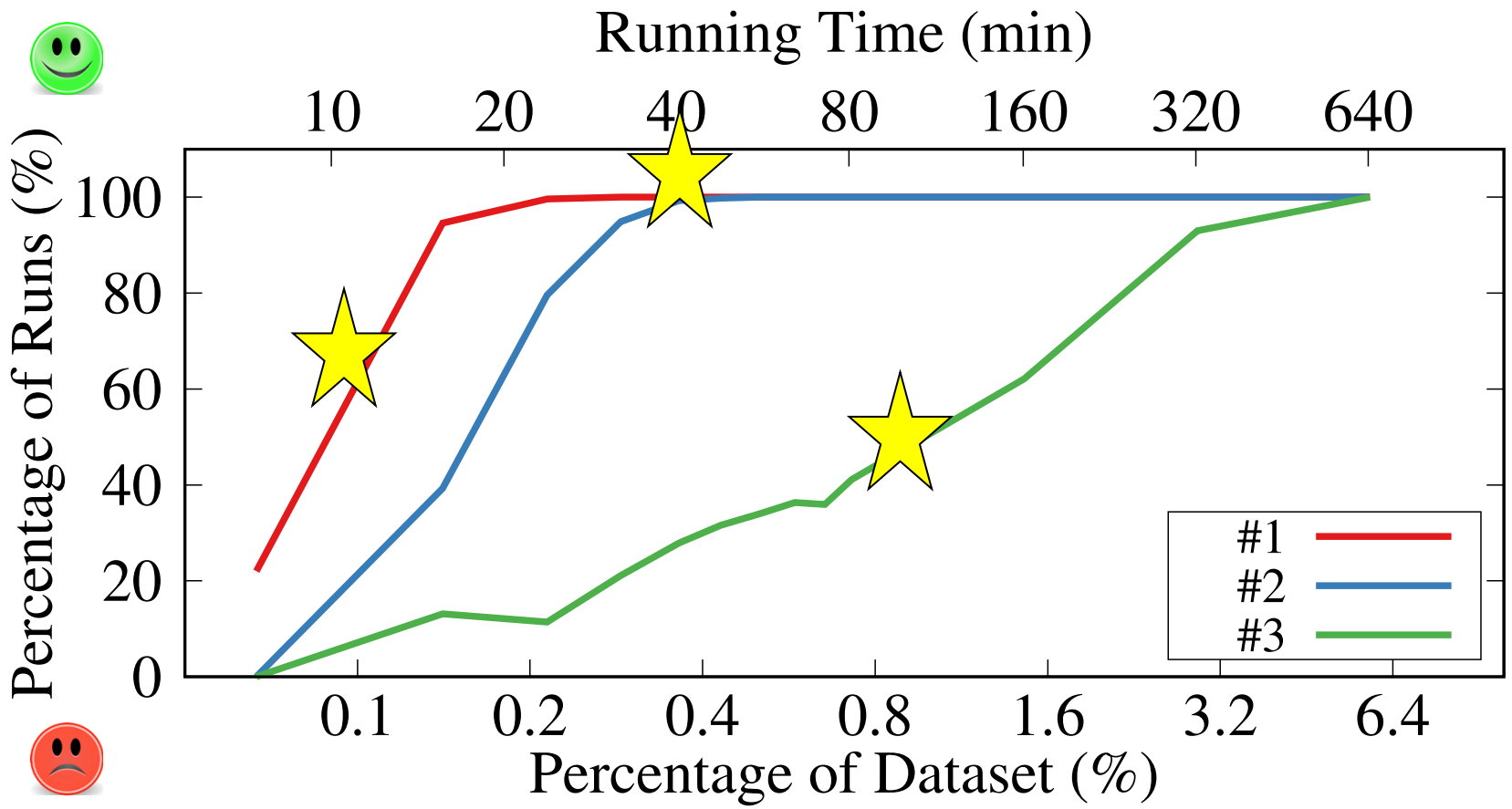
Parameter Importance Summary

Setting	Workload	F/S	#1	#2	#3	#4
S2	fileserver-10gb	Ext4	Journal Option	I/O Scheduler	Inode Size	-
S2	dbserver-10gb	Ext4	Block Size	Inode Size	I/O Scheduler	Journal Option
S2	webserver-10gb	Ext4	Inode Size	Flex BG	Block Size	Journal Option
S1	fileserver-def	Btrfs	Special Option	Node Size	Device	-
S1	webserver-def	Btrfs	-	-	-	-

Evaluation: Carver



Ext4, S1, Fileserver-default

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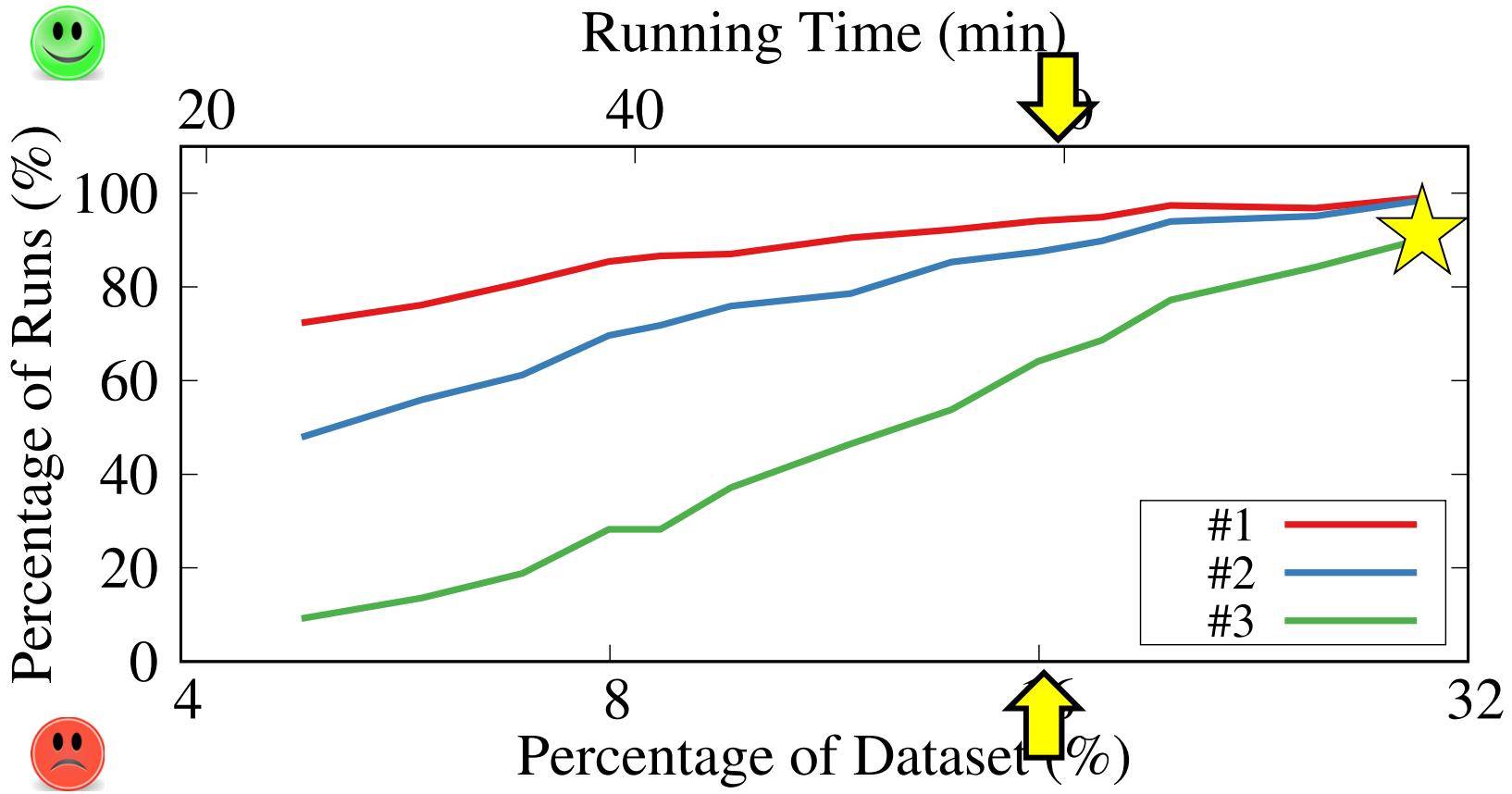
Evaluation: Carver (Cont.)



Btrfs, S1, Fileserver-default

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Related Work

- Parameter selection for systems
  - Lasso [Aken et al.]
  - Adaptive Sampling [Duan et al.]
  - Probabilistic Reasoning [Sullivan et al.]
- Auto-tuning storage systems
  - Genetic Algorithms, Deep Q-Networks, etc.
  - Comparative Study [Cao et al.]

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Conclusions

- Proposed Carver for efficiently selecting storage parameters
- Provided thorough study of storage-parameter importance
- Demonstrated Carver's efficiency by testing it on small fractions of the configuration space

Future Work

- Extend Carver to support other parameter-selection techniques
  - Group Lasso, ANOVA, etc.
- Evaluate Carver with more optimization objectives and larger storage-parameter spaces
- Extend Carver's parameter selection algorithm into multi-objective optimization
- Integrate Carver with auto-tuning algorithms

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Thank You

Q&A

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