# Performance Sensitivity Across Configuration and Workload

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**Abstract:** The original article "*Analyzing the Impact of Workloads on Modeling the Performance of Configurable Software Systems*" has been published at ICSE 2023. Software systems typically offer configuration options to customize functionality and optimize their performance. Machine learning is commonly employed to develop *performance models* by evaluating how different configurations affect performance. These models enable the estimation and enhancement of software performance based on specific configurations. However, current performance modeling approaches often overlook the impact of varying workloads on software systems. With models being frequently trained using a single workload, it raises concerns about their *reliability* when applied to diverse workloads.

We conducted an empirical study involving 25 258 configurations across nine real-world software systems operating under various workloads. This investigation assesses the susceptibility of performance models to varying workloads. Analyzing performance and coverage data, our study unveiled three key patterns: (1) certain options only influence performance when paired with particular workloads, (2) some options exhibit highly variable impacts, and (3) certain options can either improve or deteriorate performance depending on the workload. Our findings underscore the notion that performance models cannot be universally applicable across all workloads, which highlights the need to consider workload sensitivity when developing dependable performance models.

**Keywords:** Configurable Software Systems; Performance Sensitivity; Workload Variability

Modern software systems typically offer configuration options for tailoring functionality and adjusting non-functional aspects such as performance and energy usage. This relationship between configuration choices and performance can be depicted through *performance models* that link specific configurations to estimated performance values. These models are trained using a dataset of performance observations corresponding to different configurations, employing standard machine learning techniques. Once trained, the performance model can then serve as a surrogate for predicting or optimizing performance.

The workload (i.e., the input fed to a software system) can influence software system in various ways. Beyond the obvious relationship, such as performance scaling with workload size, the impact of workload variation on configurable software systems in particular remains opaque. Current performance modeling approaches tend to select workloads that mimic

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real-world application scenarios to elicit representative performance behavior. However, performance models typically rely on observations from a single workload and often overlook the workload as an essential dimension in the problem space.

The influence of workloads on software performance questions the validity of a single-workload performance model when dealing with a variety of workloads: Are workloads and configurations independent factors influencing software performance, or do they in conjunction contribute to performance variation beyond their individual effects? In essence, we are asking whether a single-workload performance model can *reliably* predict performance across different workloads or whether it is susceptible to distortion caused by workload variation.

We set out to characterize the interaction of configuration and workload when learning performance models and estimating performance. To this end, we conducted an empirical study of 25 258 configurations from nine configurable real-world software systems across multiple workloads to study the effects of workload variation on configuration-specific performance behavior [Mü23]. To further investigate driving factors for potential workload-configuration interactions, we augment performance observations with corresponding code coverage data to understand workload variation with respect to the executed code.

We found that varying the workload can distort the influence of configuration options in different, especially *non-monotonous* ways. For such workload-configuration interactions, we identified three patterns, including configuration options that are (1) influential only in conjunction specific workloads and options whose influence, (2) exhibits high variation, or (3) either improves/worsens performance depending on the workload, respectively. Some workload-configuration interactions can be attributed to differences in workload characteristics and are correlated with differences in the execution of configuration-specific code sections, outlining a path to screen for workload-sensitive configuration options.

We provide empirical evidence that performance models do not (or should, at least, not be expected to) generalize to arbitrary workloads. As a take-away message, our results underscore the necessity to consider the workload dimension when learning reliable performance models, either by varying workload characteristics alongside the configuration, or by explicitly adapting a single-workload performance model to a new workload by identifying workload-sensitive configuration options.

We make available supplementary material, including experimental measurements, and an interactive dashboard for data exploration at `https://doi.org/10.5281/zenodo.7504284`.

## Bibliography

[Mü23] Mühlbauer, Stefan; Sattler, Florian; Kaltenecker, Christian; Dorn, Johannes; Apel, Sven; Siegmund, Norbert: Analyzing the Impact of Workloads on Modeling the Performance of Configurable Software Systems. In: Proceedings of the 45th IEEE/ACM International Conference on Software Engineering (ICSE). IEEE, pp. 2089–2101, 2023.