Is Performance a Reliable Proxy for Energy Consumption?

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Abstract: Incorporating configuration options is a common mechanism to enable performance tuning of software systems. However, when it comes to reduce energy consumption, it is unclear whether such tuning capabilities are applicable in the same way. Thus, we investigated whether performance of configurable software systems can be used as a proxy for energy consumption, such that energy consumption can be optimized by tuning performance. We conducted a literature study and found a mixed picture in which some studies found a correlation, some an inverse correlation, and some no between performance and energy consumption. Based on this, we devised our own experiments on configurable software systems. With our approach, we can identify both types of options which enables the use of performance as a proxy for energy consumption. Furthermore, we provide evidence that a transfer factor between energy and performance is possible even at the method-level, thus helping developers in identifying methods that significantly increase energy consumption.

Keywords: Performance, Energy Consumption, Configurable Software Systems

1 Introduction

The original paper has been published at the International Conference on Software Engineering in 2023 [We23]. Reducing energy consumption of software systems is an important task today. While hardware consumes energy, it is the software that controls the hardware, and thereby, decides how much power is drawn by the hardware. Utilizing configuration options, users can not only customize a system's functionality, they can also tune its non-functional properties, such as energy consumption and performance. The potential of optimizing performance of a software system by changing its configuration has been shown in research and practice. However, reducing the energy consumption of software is more difficult because usually many measurements are needed in the optimization process and there is a lack of accurate and fast methods for measuring energy consumption.

In our work, we want to utilize the fact that energy consumption is power drawn over time. A common hypothesis is therefore: The longer a program run, the more energy is consumed. Based on this hypothesis we state the question: Can we use performance as a proxy for energy consumption, and thus reduce energy consumption by performance tuning of software configurations?

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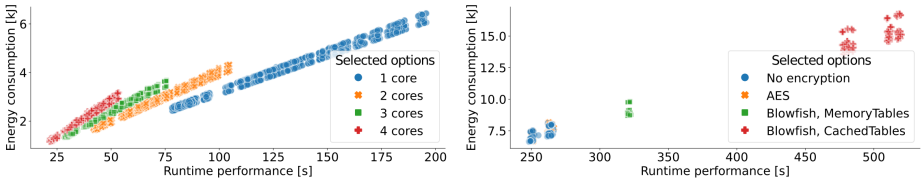

Fig. 1: Performance compared to energy consumption of all measured configurations of x264 (left) and HSQLDB (right). Colors and shapes represent different values of the selected configuration option.

2 Methodology and Results

To answer this question, we proceeded as follows: First, we study relevant literature on the relation between energy consumption and runtime performance. The results showed a mixed picture. Second, we conducted a series of experiments in which we measured runtime performance and energy consumption of a diverse set of real-world, configurable software systems. Finally, we measured runtime performance and energy consumption at the function-level to trace possible causes for correlation and non-correlation to the code.

In summary, we found strong correlations between runtime performance and energy consumption for all subject systems when considering the configuration space as a whole. So, our initial hypothesis is valid: This result can be seen in Figure 1 (left): Deciding between the different settings of option Cores results in different, but always positive correlation values. However, when looking only at parts of the configuration space (i.e., a subset of configuration options), we observe that this correlation may break down and even reverse. An example for inverse or non-correlation can be seen in Figure 1 (right). It shows clusters of configurations with similar performance but different energy consumption. Within a cluster, it is, thus, possible to reduce energy consumption without degrading performance just by changing the configuration. Causes for such non- or inverse-correlation can be traced to individual configuration options and interactions that affect certain functions in the code. In this line, we identified that few functions exhibit a distinctive transfer factor, which enables the conversion of response times to energy consumption and vice versa, depending only on a few options. Knowing these functions and the corresponding configuration options allows for the computation of these transfer factors and thereby for improving the applicability of performance as a proxy.

Bibliography

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