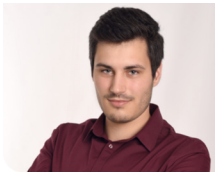
Towards Greener Software

Measuring Performance and Energy Efficiency of Enterprise Applications

Student



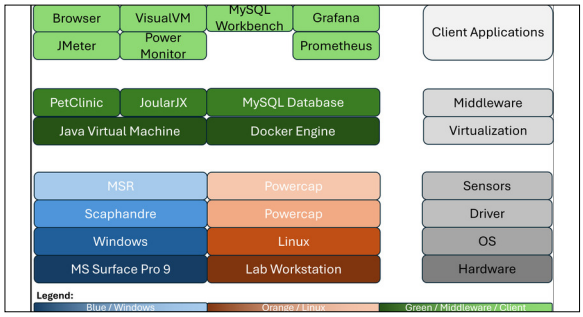
Jan Ruch

Initial Situation: Performance is an important aspect of software quality in most software applications. In recent years, the topic of energy efficiency has become increasingly important as well. Enterprise applications running in the cloud receive particular attention. Poor performance and low energy efficiency of such applications lead to high operating costs and a negative impact on the environment. Measuring performance and energy efficiency as software quality attributes becomes crucial. This research project investigates how to measure these two types of software quality attributes according to the state of the art and the practice; differences are identified and analyzed.

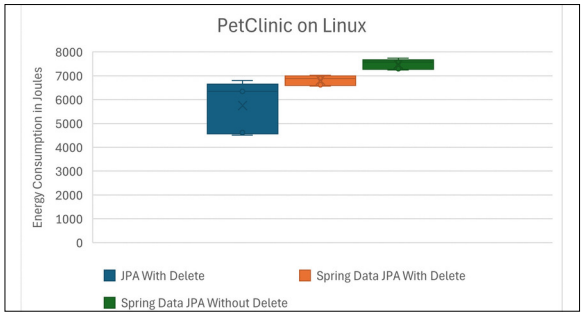
Approach: Following an empirical approach, an existing application test setup and its measurement results, publicly available in the “Growing Green Software” blog, were reproduced and compared with the behavior of a second sample application. The two respective sample applications, PetClinic and LakesideMutual, are open source-projects leveraging Java and Spring Boot; one of them comes as a set of microservices. Tools such as JMeter and JoularJX, configurations, and metrics across different test environments and enterprise applications were set up and experimented with. Contemporary software engineering practices such as Domain-Driven Design and UML were used to analyze and document the software architectures of the selected applications.

Result: A rich body of knowledge exists in the literature on performance measurements, which is useful but not sufficient in the thesis context. With respect to measuring energy consumption and energy efficiency, the software engineering literature lacks a common definition. While it proposes the term "useful work" to scope energy efficiency measurements, this term is not defined in sufficient detail; its meaning depends on the domain context. To overcome this deficit, this thesis proposes to leverage the INVEST properties of agile user stories to clarify what useful work should mean when measuring energy efficiency. The measurements confirmed that the performance and energy consumption of the sample applications are significantly influenced by external factors, such as hardware, operating system, and implementation details. They show that the relative distribution of energy consumption is comparable across different test environments and enterprise applications. Furthermore, the results suggest an inverse correlation between performance and energy efficiency when different hardware is compared. They also indicate a strong correlation when the same hardware is used but implementation details vary. The selected approach seems to be applicable in practice to measure and compare the relative energy efficiency of an enterprise application. The thesis confirmed that it is crucial to define which aspects of an enterprise application shall be evaluated, to select the right metrics, and to apply continuous and reproducible testing. While the thesis provides valuable insights, it cannot provide a holistic view of the performance and energy efficiency characteristics of enterprise applications in general. Additional configurations, tools, and metrics will be required in future work.

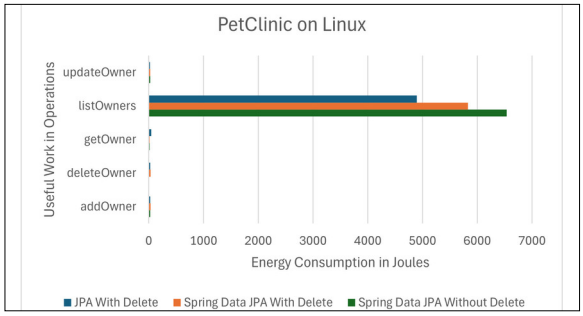
The architecture of the observed test environments and the tool deployment.
Own presentment



The total energy consumption of the PetClinic application, for three scenarios, measured with JoularJX on Linux.
Own presentment



The energy consumption of all operations involved in the pet owner API endpoint, measured with JoularJX on Linux.
Own presentment



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