Simulating Microservice-based Architectures for Resilience Assessment Enriched by Authentic Container Orchestration

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Abstract: This summary outlines the resilience simulation approach MiSim [Fr22b] published at the International Conference on Software Quality, Reliability and Security (QRS 2022) and its extension for authentic container orchestration [St23] presented at the International Conference on Performance Evaluation Methodologies and Tools (VALUETOOLS 2023).

Keywords: Microservices; Resilience; Scenarios; Simulation; Kubernetes; Container Orchestration

Context. Increased resilience compared to monolithic architectures is both one of the key promises of microservice-based architectures and a big challenge, e.g., due to the systems' distributed nature. Resilience assessment through simulation requires fewer resources than measurement-based techniques in production environments, as used in practice.

Objective. However, there is no existing simulation approach suitable for a holistic resilience assessment of microservices comprised of (i) representative fault injections, (ii) common resilience mechanisms, and (iii) time-varying workloads. The *MiSim* approach aims to overcome these limitations and fit resilience engineering practices by supporting scenario-based experiments. Also, MiSim focuses on low modeling effort by using lightweight input models and high flexibility by being extensible regarding resilience mechanisms.

Method. Figure 1 shows the workflow, inputs, and outputs of MiSim. Resilience engineers must provide experiments in the generic description format or, more intuitively, as scenarios. The experiment descriptions contain information about the workload and faultload. MiSim also requires a lightweight architecture description of the system under test, which contains information about the services, interdependencies, and the implemented resilience mechanisms. By default, MiSim can perform event-driven simulations of the common resilience mechanisms (i) circuit breaker, (ii) retry, (iii) autoscaling, (iv) load balancing, and (v) connection limiter. New mechanisms can be added by providing the implementation of these mechanisms or modifying the existing ones through a plugin system. As an extension, we complement the simulation with the implementation of Kubernetes artifacts by providing an adapter that translates events from the simulation to Kubernetes events and vice versa.

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Results. We demonstrate how MiSim simulates (1) its default resilience mechanisms and (2) fault injections — i.e., instance/service killing and latency injections. We also use TeaStore [Vo18], a reference microservice-based architecture, aiming to reproduce scaling be-
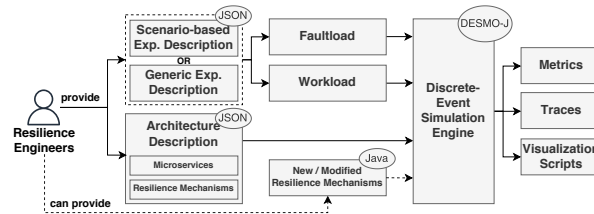

Fig. 1: MiSim overview [Fr22b]

havior from an experiment using simulation. Our results show that MiSim allows for quantitative insights into microservice-based systems' complex transient behavior by providing metrics, traces, and visualization scripts. Further, we show that a combination of simulation and real Kubernetes artifacts can correctly handle different configurations of orchestration mechanisms, boosting both the simulation's use cases and authenticity.

Conclusion. The MiSim approach is a meaningful contribution to our vision of continuous specification and verification of resilience scenarios [Fr22a] in which it can be utilized to get quick feedback on scenario satisfaction at runtime and design-time as well as for what-if-scenarios. Further, MiSim's extension allows authentic representation of container orchestration mechanisms that is useful for performance prediction of microservice applications with black-box container orchestration[4].

Data Availablility. We provide MiSim's implementation[5], the evaluation data[6], and the implementation and evaluation results for our Kubernetes extension[7].

References

[Fr22a]   Frank, S.; Hakamian, A.; Wagner, L.; Von Kistowski, J.; Van Hoorn, A.: Towards Continuous and Data-driven Specification and Verification of Resilience Scenarios. In: 2022 IEEE International Symposium on Software Reliability Engineering Workshops (ISSREW). IEEE, pp. 136–137, 2022.

[Fr22b]   Frank, S.; Wagner, L.; Hakamian, A.; Straesser, M.; van Hoorn, A.: MiSim: A Simulator for Resilience Assessment of Microservice-Based Architectures. In: 2022 IEEE 22nd International Conference on Software Quality, Reliability and Security (QRS). IEEE, pp. 1014–1025, 2022.

[St23]   Straesser, M.; Haas, P.; Frank, S.; Hakamian, A.; van Hoorn, A.; Kounev, S.: Kubernetes-in-the-Loop: Enriching Microservice Simulation Through Authentic Container Orchestration. In: Proceedings of the 16th EAI International Conference on Performance Evaluation Methodologies and Tools. (in press), Springer, 2023.

[Vo18]   Von Kistowski, J.; Eismann, S.; Schmitt, N.; Bauer, A.; Grohmann, J.; Kounev, S.: TeaStore: A micro-service reference application for benchmarking, modeling and resource management research. In: 2018 IEEE 26th International Symposium on Modeling, Analysis, and Simulation of Computer and Telecommunication Systems (MASCOTS). IEEE, pp. 223–236, 2018.

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[4] https://gepris.dfg.de/gepris/projekt/510552229
[5] https://github.com/Cambio-Project/MiSim
[6] https://doi.org/10.24433/CO.9682966.v3
[7] https://doi.org/10.24433/CO.4913288.v1