EMSA: A GPU Optimized Framework for the Sensitivity Analysis of Epidemic Models

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One of the most effective and cost-efficient methods for mitigating pandemics is through the use of mathematical techniques for intervention planning and scenario analysis. To ensure the reliability of our models, sensitivity analysis is employed among other methodologies [1]. Due to the inherent complexity of these models, sensitivity analysis often necessitates running simulations in the tens of thousands across various parameter configurations, which in turn requires innovative implementation strategies.

The objective of this development is to create a Python framework that streamlines the implementation of epidemic models and enables rapid evaluation for sensitivity analysis. To achieve this, we have introduced a novel representation for the systems of differential equations that define compartmental deterministic epidemic models. This representation facilitates the parallel evaluation of models (including on GPUs), by utilizing the *PyTorch*-based *torchode* Python library [2], which has resulted in a more than 50-fold decrease in the runtime of the benchmarked model.

In addition to performance improvements, we have focused on developing a robust, understandable, and extendable system by employing the best practices of object-oriented programming. We have also put a large emphasis on creating a user-friendly framework, thus the implementation allows for the sensitivity analysis of user-defined models with minimal code, as all necessary data can be provided through configuration files.

[1] Wu et al., Sensitivity analysis of infectious disease models: methods, advances and their application, *Journal of The Royal Society Interface*, **10(86)** (2013), 20121018.

[2] Lienen and Günnemann, torchode: A Parallel ODE Solver for PyTorch, 2022, *Preprint*, https://arxiv.org/abs/2210.12375