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Differometor: A Differentiable Interferometer Simulator for the Computational Design of Gravitational Wave Dectectors

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The traditional design of gravitational wave detectors follows a human-centric, rational approach based on domain expertise and ingenuity. However, the vast space encompassing all possible experimental configurations suggests that some powerful and unconventional detection strategies lay outside the reach of such human-driven design. An AI-based approach that scales with increasing computation promises an unbiased and complementary design alternative. A current bottleneck of this approach is the computational cost of the simulator computing the gradient of the objective function with respect to the experimental parameters. We present Differometor, a new differentiable frequency domain interferometer simulator implemented in Python using the JAX framework. Differometor closely follows the design of the established Finesse simulator and uses the plane-wave approximation to compute light field amplitudes in quasi-static, user-defined laser interferometer configurations. It can effectively model light field modulations, radiation pressure effects and quantum fluctuations of optical fields. JAX's GPU support and just-in-time compilation ensure fast runtimes, while its automatic differentiation facilitates gradient-based optimizations up to 160 times faster than numerical optimizations with Finesse. Differometor constitutes an important step towards large-scale computational design of novel gravitational wave detectors.

AI keywords

Differentiable Programming; Differentiable Simulators; Gradient-Based Optimization

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