Z113a Exploration of Feasible Optical Designs and Sensitivity Analysis Using Differentiable Programming

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In the development of observational instruments, system design and sensitivity analysis are crucial. Specifically, minimizing the deviation of objective parameters from target values and estimating allowable manufacturing tolerances both require access to the derivatives of system functions. Recent rapid advancements in differentiable programming have led to high-speed, high-accuracy automatic differentiation, which is attracting significant attention for design optimization applications.

In this study, we propose a method that uses JAX to efficiently explore the feasible design space of realizable optical systems while simultaneously performing sensitivity analysis for each design parameter. This approach aims to identify solutions that are robust to manufacturing errors, even in scenarios where no analytical solution exists.

As a test case, we focus on the Range Simulator (RS)—an apparatus under development for ground testing of an inter-satellite interferometer. The RS simulates long-distance light propagation on an optical bench, and no experimental realizations have been reported to date. By applying our method, we explored novel feasible designs for the RS and evaluated the sensitivity of its parameters.

Our results revealed a viable three-lens configuration and, through sensitivity analysis, demonstrated a trade-off relationship between the overall scale of the apparatus and its manufacturing tolerances.