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Fast computation of derivative based sensitivities of PSHA models via algorithmic differentiation

Hernan Leövey (1), Christian Molkenthin (2), Frank Scherbaum (2), Andreas Griewank (1), Nicolas Kuehn (3), and Peter Stafford (4)

(1) Department of Mathematics, Humboldt-University Berlin, Germany, (2) Institute of Earth- \& Environmental Science, University of Potsdam, Germany, (3) Pacific Earthquake Engineering Research Center, University of California Berkeley, USA, (4) Department of Civil and Environmental Engineering, Imperial College London, UK

Probabilistic seismic hazard analysis (PSHA) is the preferred tool for estimation of potential ground-shaking hazard due to future earthquakes at a site of interest. A modern PSHA represents a complex framework which combines different models with possible many inputs. Sensitivity analysis is a valuable tool for quantifying changes of a model output as inputs are perturbed, identifying critical input parameters and obtaining insight in the model behavior. Differential sensitivity analysis relies on calculating first-order partial derivatives of the model output with respect to its inputs. Moreover, derivative based global sensitivity measures (Sobol' & Kucherenko '09) can be practically used to detect non-essential inputs of the models, thus restricting the focus of attention to a possible much smaller set of inputs. Nevertheless, obtaining first-order partial derivatives of complex models with traditional approaches can be very challenging, and usually increases the computation complexity linearly with the number of inputs appearing in the models.

In this study we show how Algorithmic Differentiation (AD) tools can be used in a complex framework such as PSHA to successfully estimate derivative based sensitivities, as is the case in various other domains such as meteorology or aerodynamics, without no significant increase in the computation complexity required for the original computations. First we demonstrate the feasibility of the AD methodology by comparing AD derived sensitivities to analytically derived sensitivities for a basic case of PSHA using a simple ground-motion prediction equation. In a second step, we derive sensitivities via AD for a more complex PSHA study using a ground motion attenuation relation based on a stochastic method to simulate strong motion. The presented approach is general enough to accommodate more advanced PSHA studies of higher complexity.