FORCsensei: A machine learning framework to estimate optimized first-order reversal curve distributions

David Heslop[1,2], Andrew Roberts[1,2], *Hirokuni Oda[2], Xiang Zhao[1,2], Richard Harrison[3], Adrian Muxworthy[4], Pengxiang Hu[1,2], Tetsuro Sato[2]

1. Australian National University, 2. Institute of Geology and Geoinformation, Geological Survey of Japan, AIST, 3. University of Cambridge, 4. Imperial College London

First-order reversal curve (FORC) distributions are a powerful diagnostic tool for characterizing and quantifying magnetization processes in fine magnetic particle systems. Estimation of FORC distributions requires computation of the second-order mixed derivative of noisy magnetic hysteresis data. This operation amplifies measurement noise and for weakly magnetic systems it can compromise estimation of a FORC distribution. Several processing schemes, typically based on local polynomial regression, have been developed to produce smoothed FORC distributions that suppress detrimental noise. As FORC analysis has become more quantitative, the smoothed distribution needs to be consistent with the measurement data from which it was estimated. This can be a challenging task even for expert users, who must subjectively adjust parameters that define the form and extent of smoothing until a satisfactory FORC distribution is obtained. For non-expert users, estimation of FORC distributions using inappropriate smoothing parameters can produce heavily distorted results corrupted by processing artifacts, which in turn can lead to spurious inferences concerning the magnetic system under investigation. We have developed a statistical machine learning framework based on probabilistic model comparison to guide estimation of FORC distributions. An intuitive approach is presented that reveals which regions of a FORC distribution may have been smoothed inappropriately. Our machine learning approach will objectively select an optimal FORC distribution probabilistically, which will automate the derivative estimation process for both expert and non-expert users.

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