
Efficient and noise-resilient nonlinear elastic simulations via a continuous data-driven framework

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Abstract

This work introduces a computational data-driven mechanics framework based on a continuous dataspace, improving upon the traditional data-driven methodology (1). Conventional data-driven computational mechanics methodology relies on finite, discrete datasets as the dataspace and iterative projections between the dataspace and the constraint space defined by the problem setting. However, using discrete datasets as the dataspace introduces drawbacks such as reduced accuracy due to noise and outliers in the dataspace (2), and high computational cost needed for locating optimal datapoints within the large and multidimensional datasets (3). The proposed framework addresses these issues by replacing the discrete dataset with a continuous dataspace extracted via Gaussian mixture modelling. This continuous dataspace acts as a data density field that is a sum of a finite number of Gaussian kernels and can be used to assess the likelihood of points attaining the material behaviour. Consequently, it mitigates the effect of noise and outliers on the solution accuracy. Hence it has been observed that the proposed framework outperforms the conventional one in terms of accuracy for varying noise levels. Moreover, the framework streamlines data-to-constraint space projections by utilizing a search direction derived from the continuous dataspace, therefore significantly reduces the computational cost by eliminating the need for search queries in discrete datasets as the computational cost of the conventional framework is shown to scale exponentially with respect to that of the newly introduced framework with increasing dataset size. Numerical experiments in both one and two dimensional problems validate the framework's ability to improve both accuracy and computational efficiency.

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