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Efficient exploration of quantified uncertainty in granular crystals

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ABSTRACT

Granular crystals present unique nonlinear properties that support standing waves. These depend on precompression and impurities. Thus, they can be used for different applications such as impact and shock dissipation. There are different models which rely on reasonable approximations and assumptions. While experimental results show good agreement with theory, there are experimental errors that are not easily explained and are usually attributed to the approximations made and phenomena that are not accounted for. This might be the result of not quantifying the uncertainty, since variables like the grain size, position, mass and Young modulus, of each particle, are uncertain. Building a response surface is computationally expensive, because the underlying mapping to be learned is a high dimensional problem. This work presents a way of quantifying uncertainty in granular crystals in a computationally efficient way. To accomplish this, a low dimensional response surface is approximated through the method of active subspaces. Within this framework, special structure within the inputs is exploited to project it onto a lower dimensional manifold. The problem of subspace approximation is then treated as an optimization problem, with the use of the Bayesian Information Criterion (BIC). We treat the underlying function to be learned as a Gaussian Process and use Gaussian process regression to generate predictive distributions for test inputs. Distributions obtained through these methods, accurately reproduce the observed experimental errors, depending on the uncertainty introduced in different inputs. Thus, allowing for the better design of experimental setups as well running virtual experiments; saving time and resources.

KEYWORDS

Gaussian processes, granular crystals, impact dissipation, uncertainty quantification.