Machine learning based prediction of extreme events in networks of coupled mechanical oscillators

Popular summary

Many phenomena in a wide range of physical domains and engineering applications have got observable properties that are normally distributed, that is, they obey Gausian statistics. Gausian-distributed random variables and processes are particularly easy to manipulate algebraically. However, in many applications, random variables have significantly non-Gausian character. Frequently, the “long tails” of their distribution, which contain **extreme**, but **rare events**, are particularly important for a complete understanding of the phenomena in question.

Rare or extreme events are the events that occur with low frequency and often refers to infrequent events that have widespread impact and which might destabilize systems (for example, stock markets, ocean wave intensity, or society). Rare events encompass natural phenomena (major earthquakes, tsunamis, hurricanes, floods, asteroid impacts, solar flares, etc.), industrial accidents, financial and commodity market crashes, etc.), as well as phenomena for which natural and anthropogenic factors interact in complex ways (epidemic disease spread, global warming-related changes in climate and weather, etc.). In engineering systems one can mention mechanical part failure and turbine shocks.

Rare event modeling refers to efforts to characterize the statistical distribution parameters, generative processes or dynamics that govern the occurrence of statistically rare events, including but not limited to high-impact natural or human-made catastrophes. Such “modeling” may include a wide range of approaches, including, most notably, statistical models derived from historical event data and computational software models that attempt to simulate rare event processes and dynamics. Rare event modelling also encompasses efforts to forecast the occurrence of similar events over some future time horizon, which may be of interest for both scholar and applied purposes.

Understanding and predicting extreme events as well as the related anomalous statistics is a grand challenge in complex natural and man-made systems. Deep convolutional neural networks and machine learning algorithms can help to make this prediction easier and more accurate.

Machine learning usually seen as a part of artificial intelligence is the study of computer algorithms that can improve automatically through experience and by the use of data. Machine learning algorithms build a model based on sample data, known as training data, in order to make predictions or decisions without being explicitly programmed to do so. Learning algorithms work on the basis that strategies, algorithms, and inferences that worked well in the past are likely to continue working well in future. Machine learning programs can perform tasks without being explicitly programmed to do so. It involves computers learning from data provided so that they carry out certain tasks. For simple tasks assigned to computers, it is possible to program algorithms telling the machine how to execute all steps required to solve the problem at hand; on the computer's part, no learning is needed. For more advanced tasks, it can be challenging for a human to manually create the needed algorithms. In practice, it can turn out to be more effective to help the machine develop its own algorithm, rather than having human programmers specify every needed step.

Machine learning algorithms are used in a wide variety of applications, such as medicine, email filtering, speech recognition and computer vision, weather prediction where it is difficult or unfeasible to develop conventional algorithms to perform the needed tasks. In this project, we develop and analyze the performance of algorithms suitable for prediction of extreme events in the networks of coupled oscillators. The corollary objective, is to anticipate and transpose, thanks to the deep understanding of the mechanisms leading to extreme events, their implications in several well identified technological contexts.