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Multi-fidelity Data Aggregation using Convolutional Neural Networks

-In many domains in science and engineering, multiple computational and experimental models are generally available to describe a system of interest. These models differ from each other in the level of fidelity and cost. Typically, computationally or experimentally expensive high-fidelity (HF) models describe a system with a high accuracy. In contrast, low-fidelity (LF) models take less time to run but are less accurate. In recent years, there have been growing interests in utilizing multi-fidelity models which combine the advantages of HF and LF models to achieve accuracy at a reasonable cost.

Neural networks (NNs) are a subset of machine learning and are at the heart of deep learning algorithms. NNs can deal with arbitrary nonlinearities in high dimensions. Recently, efforts of applying NNs as surrogate models have been made to achieve multi-fidelity models. An important feature of applying NNs to achieve multi-fidelity modeling is to learn the relationship between low- and high-fidelity models and how best the NNs can exploit that relationship.

Researchers at Arizona State University have developed a neural network (NN) model for multi-fidelity modeling. The model has three components: multi-fidelity data compiling, multi-fidelity perceptive field and convolution, and deep NN for mapping. This model captures and utilizes implicit relationships between any high-fidelity datum and all available low-fidelity data using a defined local perspective field and convolution.

There are several unique benefits of this model: (1) multi-fidelity data is treated as image data and processed using convolutional NNs; (2) the flexibility of nonlinear mapping in NN facilitates the multi-fidelity aggregation and does not need to assume specific relationships among multiple fidelities; and (3) multi-fidelity data is not assumed to be at the same order or from the same physical mechanisms.

Related publication: Multi-fidelity Data Aggregation using Convolutional Neural Networks

Potential Applications:

- In engineering and science, for design optimization, predictions, and/or computations, in the following tasks:
  - Simulation testing
  - Image analysis
  - Speech recognition
  - Material discovery

Benefits and Advantages:

- Can handle data aggregation from multiple sources across different scales, such as different order derivatives and other correlated phenomenon data in a single framework
- Fully exploits the relationship between low- and high-fidelity data
  - Aims to capture and utilize the relationship between any high-fidelity datum with all available low-fidelity data, instead of just a point-to-point relationship (i.e., a high-fidelity datum with one corresponding low-fidelity datum)
- Only one-time training is needed