A "Physical" Law of Data Separation in Deep Learning, with Some Ramblings

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The impressive progress in the field of deep learning over the past years has been largely guided by intricate heuristics and strategies. For future advancements, however, it is crucial to build a rigorous theoretical framework. Unfortunately, the complex details of contemporary neural networks make this a daunting task. For near-term purposes, a practical alternative is to develop a mathematically tractable surrogate model that yet maintains many characteristics of deep learning models. This talk will introduce a model of this kind as a tool toward understanding deep learning. This model has demonstrated its utility in explaining an empirical pattern in deep learning known as neural collapse and in predicting a hitherto unknown phenomenon during deep learning training.

In addition, this talk will also explore how data are processed in the intermediate of neural networks. In particular, we will introduce the law of equi-separation, a pervasive empirical phenomenon that delineates the progression of data separation across the layers of a neural network. Our extensive computational studies reveal that neural networks enhance data separation layer-by-layer in a simple exponential pattern, suggesting that each layer contributes equally to the process. This law has several implications on the robustness and generalization of deep learning, and challenges the adequacy of some existing approaches to understanding deep learning.