Internship Proposal MSIAM (DS, MSCI)

Wavelet-Nets: Construction of wavelet-type neural networks & application to image classification

(Research)

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Context: Deep learning frameworks provide computational models that are composed of several processing layers to learn data representations with multiple levels of abstraction. These methods have dramatically improved the state-of-the-art in speech recognition, visual object recognition, object detection, and in many other domains such as drug discovery and genomics. They discover intricate structure in large datasets by using the backpropagation algorithm for learning the internal model parameters. In other words, determine how the parameters should change to better compute the representation in each layer from the one computed in the previous layer. Deep convolutional networks introduced by LeCun and colleagues have resulted in breakthroughs in processing images, video, speech and audio, and recurrent networks have made a impact on sequential data, such as text and speech.

Deep convolutional neural networks (CNN) are implemented with linear convolutions followed by nonlinearities, over typically more than five layers. Experiments show that CNNs are computing progressively more powerful invariants as network depth increases, but these relations are complex to analyze due to the large number of network weights and nonlinearities. Therefore, a full mathematical understanding of the properties of CNNs continues to remain a challenging issue.

On the other hand, the wavelet scattering network, introduced by S. Mallat in 2013 [3], built a network with fixed parameters (the wavelet filters), which do not need to be learned. In this scattering network, the convolutions are computed using wavelet kernels, followed by a modulus pooling (nonlinear) operator. Since the wavelet transform provides powerful properties (translation and scale invariance), it is possible to analyze the stability of the network [4].

There have been a few attempts to introduce wavelet filters directly in neural networks, wherein the parameters of the wavelets (translation, scale) are learned [1, 2].

Objectives: The aim of this Master thesis project is to construct a novel convolutional neural network, based on wavelet filters learned by the network, with an alternative approach than these proposed in recent publications [1, 2]. The first part of the work will be an effective construction of the network (stochastic gradient, etc.), and then its implementation and benchmark evaluation. In the second part, invariances of the network will be studied, from an experimental as well as a mathematical point of view, similar to in spirit to [4]. Benchmark evaluation will be on the image classification problem, e.g., [5], and implemented in Matlab or Python.

References

[1] A. Alexandridis and A. Zapranis, Wavelet Neural Networks: A Practical Guide. Neural Networks, 42. (2013).
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[3] J. Bruna and S. Mallat, Invariant Scattering Convolution Networks, IEEE Trans. PAMI 35. (2013).
[4] S. Mallat, Understanding deep convolutional networks, Phil. Trans. R. Soc. A 374. (2016).
[5] `http://www.image-net.org`.