

Deep Kernel Learning based Gaussian Processes for Bayesian Image Regression Analysis

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Abstract

In neuroimaging applications, different types of regression models have been widely adopted to study the complex associations between images and clinical variables, including scalar-on-image regression, image-on-scalar regression, and image-on-image regression. There are many challenging problems in model interpretations, statistical inferences and predictions in those type of models. To address those issues, we propose a general Bayesian modeling framework for the image regression problems by integrating deep neural networks (DNN) and Gaussian processes (GP) with kernel learning. The proposed framework consists of two levels of hierarchy. At level 1, we assume images as realizations of different GPs and project them on lower dimensional Euclidean spaces using a kernel expansion approach. We adopt a novel DNN based approach to covariance kernel learning of the GPs which provides efficient and accurate image projections. At level 2, we specify the associations between the projected images and other predictors using Bayesian DNNs. We develop efficient variational inference algorithms for posterior computation. We compare the performance of the proposed method with the state-of-the-art methods via extensive numerical experiments on synthetic images from the benchmark datasets as well as analysis of the fMRI data in the large-scale imaging studies.