CS231A Course Project Proposal

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Abstract

The space of natural images is both high-dimensional and has striking non-Gaussian, higher-order statistical structure. A key part of understanding the redundancy of natural scenes is understanding the entropy of image patches. Entropy allows us to place a number on the information content of image patches, and bounds optimal compression schemes. This project aims to compare different methods for estimating the entropy of natural image patches, and to compare how these estimates scale with increasing patch sizes.

1. Background

A few previous studies have developed methods for estimating the entropy of image patches. Chandler and Field use an approximation that relies on nearest-neighbor (NN) distances. It has been shown (Kozachenko and Leonenko 1987) that the average log NN distance can be used to estimate the entropy without estimating the probability distribution $p(x)$. Another approach involves fitting maximum entropy models to natural images. These models are guaranteed to have the largest entropy given certain statistics observed from data. This was the approach taken by (Bethge and Berens, *NIPS*, 2007), who fit an approximate maximum entropy model and used it to estimate the entropy of image patches.

2. Methods

Image patches will be either generated from known distributions (white/colored noise) or sampled from the van Hateren natural image database.

The entropy of image patches drawn from these distributions will be computed using two methods discussed in the previous literature. The first is involves using nearest-neighbor methods (Chandler and Field, *J. Opt. Soc.*, 2007) and the second involves approximate maximum entropy models. Entropy estimates will be computed both for (1) increasing sample sizes and (2) increasing dimensionality (patch sizes). One novel contribution of this work will be to compare and contrast the two methods. Currently, it is not clear how the reliability of the entropy estimates will scale as the dimensionality of the patches increases, but I will be able to say something about this given my method.

A secondary aim that I am thinking about pursuing involves performing dimensionality reduction (for example, with PCA) on the set of natural image patches, and then computing the entropy of the distributions in the low-dimensional space. It is not clear how entropy will be affected by different dimensionality reduction techniques, and by the size of the low-dimensional space. The above methods of estimating entropy will yield more reliable estimates of the entropy given low-dimensional representations, and will allow me to extrapolate the entropy estimate to larger image patch sizes.

3. Evaluation

The ultimate goal of this project is to obtain plots of the entropy (in bits per pixel) of image patches for different patch sizes. To validate the methods, a comparison of how the various metrics perform when estimating image patches drawn from known distributions with fixed statistical structure (Gaussian noise) will be used as a baseline for comparison, since the entropy of these distributions is known analytically.

Once the methods have been validated, entropy estimates of the different measures on natural image patches will be compared. Different curves will be shown for measures of the entropy made using different methods. Another criterion for evaluation is comparing the consistency of different entropy estimates for increasing sample sizes. Finally, these results will be compared with recent entropy estimates from the literature.

4. Appendix

This course project is unique to this course, and not part of other research or coursework. I plan on working alone for this project.