PhD Proposal MAP-I

Image analysis through compression-based complexity surfaces

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1 Motivation

The Kolmogorov complexity of a string A, $K(A)$, is defined as the minimum size of a program that produces A and stops. A major drawback of the Kolmogorov complexity (also known as the algorithmic entropy) is that it is not computable. Therefore, we are forced to compute approximations that provide upper bounds on the true complexity of the string. Compression algorithms seem to provide a natural way of approximating the Kolmogorov complexity, because, together with the appropriate decoder, a bitstream produced by a lossless compression algorithm allows reconstructing the original string. The number of bits required for representing these two components (decoder and bitstream) can be viewed as an estimate of the Kolmogorov complexity of the string. Moreover, looking for better compression algorithms is directly related to the problem of improving the complexity bounds.

This theory and the relations to data compression are known for some time and have been applied to a number of domains. Its potential interest for image analysis is great, but the nature of the commonly available compression algorithms has been a major obstacle to further progress. In fact, the compression methods that can be used for approximating the Kolmogorov complexity need to comply to some fundamental conditions. Basically, the compression algorithm needs to build an internal model of the data, i.e., it needs to collect statistical information regarding data dependencies.

The Lempel-Ziv family of compression algorithms is among the techniques that create internal data models. These are also the most used compression algorithms in compression-based complexity applications, including those reported in the imaging field. However, it happens that, although the Lempel-Ziv compression techniques are quite effective for uni-dimensional data, they do not perform well in multi-dimensional data and, therefore, in images. Moreover, the state-of-the-art image coding techniques, such as the JPEG family of standards, rely of statistical encoders that assume data independence (the data is previously decorrelated by a transform or predictive stage) and, therefore, cannot be used for the purpose of conditional complexity estimation, i.e., for estimating $K(A|B)$.

2 Objectives

We believe that the main reason for the lack of a much larger number of applications relying on compression-based image complexity is the use of compression techniques that are inappropriate for images, such as those based on the Lempel-Ziv paradigm. We will introduce advances in this important topic using our knowledge in the development of efficient image coding techniques that are based on sophisticated finite-context models (also known as Markov models).

The main idea is to explore models (in this case, finite-context models), that can capture, in a compact form, the most relevant features of a given image or image region and using them for searching regions with similar characteristics in other images. A finite-context model provides, on a symbol by symbol basis, an information measure that is basically the number of bits that are required to represent the symbol, conditioned by the accumulated knowledge of all past symbols. This information will be used to build complexity surfaces, i.e., images where the intensity of the pixels indicate how much complex a certain region of the image under analysis is.

There are several challenges that need to be addressed, such as creating rotation-invariant models, coping with the exponential growth of the finite-context models as the size of the alphabet increases and relating the output of the model (which will be a two-dimensional information-content map) with the degree of similarity.