Bitwise Structured Prediction Model for Lossless Image Coding

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Context base adaptive prediction is widely used to catch the local statistics or structural information in lossless image coding. Consequently, the prediction for edges and oscillatory regions (e.g. texture) is concerned in mass of literature. The edge-directed prediction (EDP) in [1] demonstrated the edge-directed property of LS-based adaptation that the improvement of the prediction performance is primarily around the edge areas. Matsuda et al. [2] proposed the probabilistic modeling of prediction errors in the sense of practical coding efficiency, and iteratively optimized its parameters based on the individual images to achieve the best coding performance. In this paper, we propose the bitwise structured prediction model for lossless image coding, especially for the oscillatory regions. The learning-based model utilizes the regular features obtained from the predicted local data. At first, the pixel-wise prediction is decomposed into the bitwise ones. In each bit plane, the prediction of the current bit is simplified to the max margin estimation for the 0/1 prediction problem and obtained directly conditioned on the neighboring predicted bits. Furthermore, since the decreasing dependencies of neighboring bits in lower bit plane lead to the turbulence of predictive results, the structured prediction is proposed to establish the Markov network to constrain the outputs of the bit planes, and suppress the prediction errors with a well-defined loss function. Consequently, the min-max formulation is proposed for the concurrent optimization for maximizing the 0/1 margin of all the bit planes.

$$\begin{cases} \min \frac{1}{2}\|\mathbf{w}\|^2 + C\sum_i \xi_i \\ \text{s.t.} \quad \mathbf{w}^T\mathbf{f}_i\left(\mathbf{x}_i, \mathbf{y}_i\right) + \xi_i \geq \max_{\mathbf{y}} \left(\mathbf{w}^T\mathbf{f}_i\left(\mathbf{x}_i, \mathbf{y}\right) + \mathcal{L}\left(\mathbf{x}_i, \mathbf{y}_i, \mathbf{y}\right)\right) \quad \forall i \end{cases} \tag{1}$$

In (1), the feature function is $f_i\left(\mathbf{x}_i, \mathbf{y}\right) = P\left(\mathbf{y} = \mathbf{1}|\mathbf{x}_i\right)$ and the loss function is defined as the predictive error of each pixel, $\mathcal{L}\left(\mathbf{x}_i, \mathbf{y}_i, \mathbf{y}\right) = \sum_j 2^j\left(\mathbf{y}_i^{(j)} - \mathbf{y}^{(j)}\right)$. Taking the neighboring predicted pixels as training data ($\mathbf{x}_i$ for contexts and $\mathbf{y}_i$ for obtained prediction), we build the max margin Markov network [3] to catch the regular features and learn their weight vectors $\mathbf{w}$, and hence, make an effective prediction $\hat{\mathbf{y}} = \arg\max_{\mathbf{y}} \mathbf{w}^T\mathbf{f}$ for the current pixel. Since the loss function is decomposable over all the bit planes and corresponding contexts, the prediction is asymptotically consistent with the training results in the sense of the loss function. In experimental validation, around 20% improvements in coding performance for oscillatory blocks taken from the natural images are witnessed when compared with EDP [1] and MRP [2].

References

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