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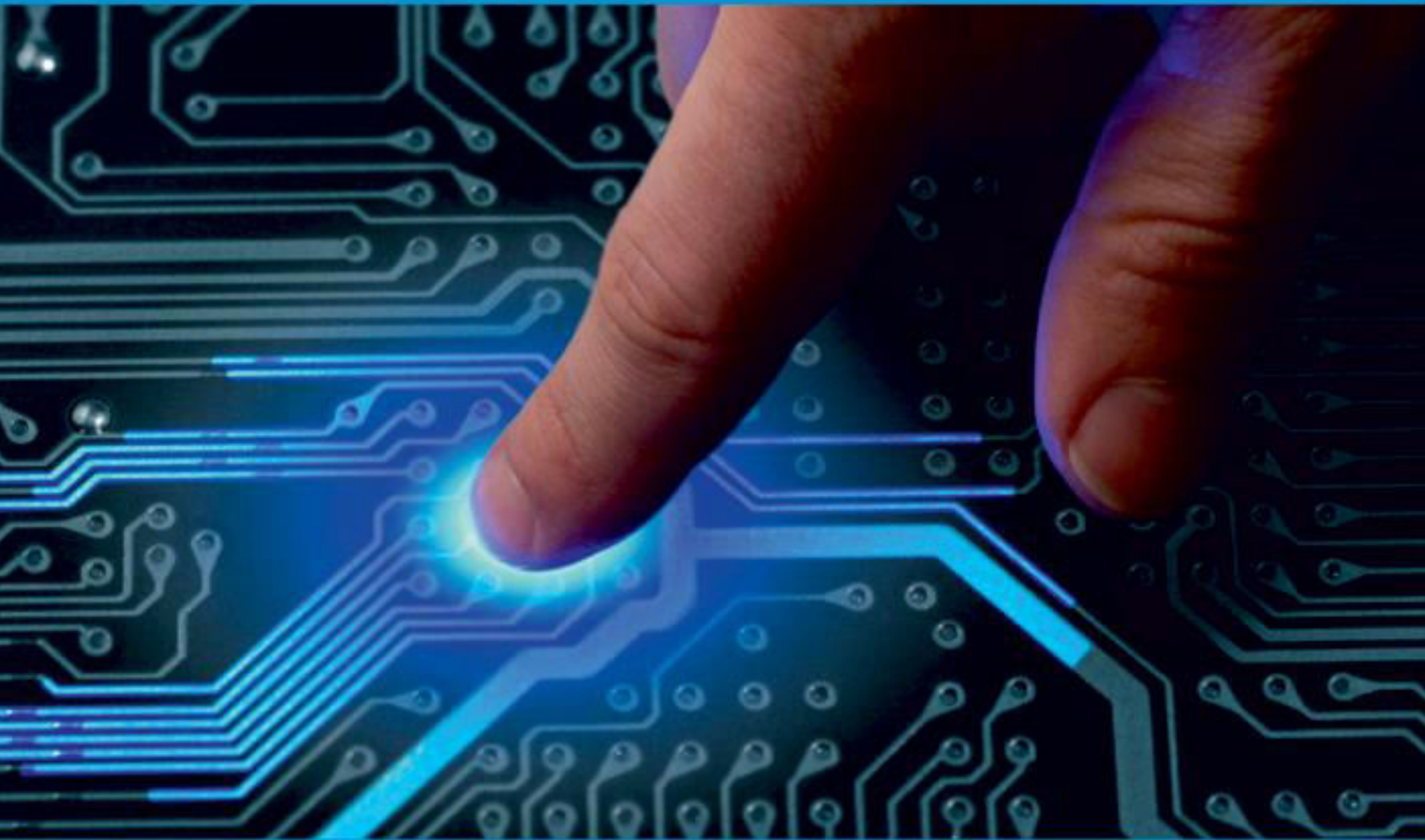

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Spherical Coding Algorithm for Wavelet Image Compression

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ABSTRACT: The success of adaptive models is a direct consequence of the special characteristics of image information. Natural im-ages consist of large smooth areas with localized high-frequency structures (i.e., edges) separating them. Edges and texture come in arbitrary locations, orientations, shapes, and sizes in natural images. Since high-frequency information is rather localized, even coarse level information about the location of high activity areas allows the coding methods to be successfully adapted to the statistics of different regions. In other words, using such "lo-cation information," wavelet subbands are modeled as nonho-mogeneous processes and coded accordingly.

I.INTRODUCTION

Recognizing the spatially changing properties of wavelet subbands is crucial for accurate modeling. Equally important is the optimal allocation of bitrate to different parts of a subband having distinct statistical characteristics. Sophisticated adaptive techniques fine tune models for each coefficient based on the context of its local (scale and/or spatial) neighborhood. A good example is the EQ coder [10], which uses a generalized Gaussian distribution (GGD) with spatially adapted variance for modeling each subband; the variance at each point is es-timated from the decoded values in its causal neighborhood unless all the neighborhood coefficients are quantized to zero. Based on the estimated variances, the coefficients are coded in a way that yields overall rate-distortion optimality.

Despite their success, the EQ coder and other adaptive methods could only offer a restricted view of image informa-tion in the wavelet domain. For instance, zerotrees of EZW coder [4] are able to provide a rather structured separation between significant and insignificant sets of coefficients. The EQ coder is more flexible; however, because of the way the variances are estimated, it assumes a slowly changing variance field for the wavelet subband. It is doubtful whether this level of adaptivity is adequate to accurately model the rich variety of local statistics of wavelet coefficients. A modeling mismatch for each coefficient will contribute to the loss of coding efficiency for the overall image. We claim that parametric descriptions of wavelet coefficient distributions are especially prone to mismatches. In other words, the wavelet image model should not be tied down to a fixed parametric description. A more adaptive coding approach should be developed, which updates its modeling paradigm locally as more information becomes available about the underlying wavelet coefficients.

In this paper, we develop a wavelet-based representation that is general, flexible and realistic. The "spherical representation" is a hierarchical description of how total coefficient energy gets distributed within each wavelet subband. A hierarchical tree of subband energy is formed by summing up the squared coeffi-cients. Phase variables are defined that describe how the energy in a given region is split into energies of two sub-regions. Phase variables are coded based on a simple and effective model. The nonhomogeneity of wavelet subbands is handled through this nonparametric model of the hierarchy. We discuss why the spherical coding framework is more robust against modeling mismatches than typical parametric techniques. In particular, we explain how our coder improves the coding efficiency by allocating total bitrate according to the local sum of energies within the subband. The local energy is used to adapt the coder to the local statistics of wavelet coefficients. We claim that this approach makes it possible to build highly adaptive and flexible coding algorithms.

Section II defines what modeling mismatch is and shows its detrimental effects on the coder performance using a simple ex-ample. Section III motivates and explains the spherical repre-sentation, and discusses why this representation is more robust against modeling mismatch while coding the wavelet subbands. Then, Section IV

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describes the details of the spherical coding algorithm. In Section V, the algorithm is tested on standard test images. Compared to some of the state-of-art wavelet coders, the spherical coding algorithm provides better or as good coding performance.

II. EFFECTS OF MODELING MISMATCH IN CODING

Mismatch in source coding indicates the loss of coding efficiency resulting when a coder optimized for a certain source model is applied to a different model. This is an important problem in image coding, since there is no single source model that can successfully describe a variety of different image characteristics. Edges, texture, smooth regions require different type of characterizations. It is not easy to determine the exact statistical nature of each such region. Even if we assume that we could develop correct models for each and every pixel or wavelet coefficient of the image, we will probably need a large set of parameters to define these distributions and this incurs a heavy cost as side information for the coder. On the other hand, if the parametrization is restricted in some way, as it is done in all wavelet coders, modeling mismatch seems inevitable.

III.CONCLUSION

We provide a simple example to show quantitatively the ef-fects of mismatch. In lossless coding, the performance loss due to mismatch is measured by the relative entropy between the two distributions, i.e., the distribution for which the coder is de-signed and the distribution to which the coder is applied. For lossy coding, results from high-rate vector quantization theory can be used to show that relative entropy between two con-tinuous distributions is a good representative of the mismatch [13]. Suppose that we apply the optimal coder designed for an i.i.d. zero-mean Gaussian process to an independent nonhomo-geneous zero-mean Gaussian process with changing variances.

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