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A Wavelet Perspective on Variational Perceptually-Inspired Color Enhancement

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Abstract The issue of perceptually-inspired correction of color and contrast in digital images has been recently analyzed with the help of variational principles. These techniques allowed building a general framework in which the action of many already existing algorithms can be more easily understood and compared in terms of intensification of local contrast and control of dispersion around the average intensity value. In this paper we analyze this issue from the dual perspective of wavelet theory, showing that it is possible to build energy functionals of wavelet coefficients that lead to a multilevel perceptually-inspired color correction. By computing the Euler–Lagrange equations associated to the wavelet-based functionals we were able to find an analytical formula for the modification of wavelet detail coefficients that overcomes the problem of an ad-hoc selection based on empirical considerations. Besides these theoretical results, the wavelet perspective provides the computational advantage of generating much faster algorithms in comparison with the spatial variational framework.

Keywords Local contrast enhancement · Wavelets · Color image processing · Variational methods

Mathematics Subject Classification 68U10 · 94A08 · 35A15

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1 Introduction

Perceptual-inspired correction of color images aims at modifying the chromatic attributes of digital images through transformations that mimic the human visual system (HVS) behavior from a phenomenological and/or neurophysiological perspective. The judgement about the effectiveness of such methods is in general performed through panel tests and their use can be found in many fields as e.g. computational photography, image quality, interior design, robotic vision and color normalization for multiple-camera systems. It must be underlined that these algorithms do not belong to the category of color vision models, which instead try to reproduce color appearance of objects surfaces and whose success is measured in terms of how close the values they predict correlate with the measured appearances, such as color matching to a standard reference.

In recent years, variational techniques have been applied to study this issue, in particular, in Palma-Amestoy et al. (2009) a set of basic phenomenological properties of the HVS have been used to select a class of energy functionals whose minimization gives rise to perceptual color correction. These functionals are defined on the set of image functions and their minimization produces two opposite effects: local contrast enhancement and adjustment to the average image value. The *balance between these opposite actions* realizes a color rearrangement that is able to highly reduce color cast and improve detail visibility while maintaining an appearance that is judged as 'natural' by panel tests. Besides these results, the variational framework provides a theoretical framework in which existing color correction models can be more easily analyzed and compared.

The major disadvantage of the variational method just described is related to its high computational complexity, which is $\mathcal{O}(N^2)$, N being the number of pixels in a given

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