UNIFIED MORPHOLOGICAL COLOR PROCESSING FRAMEWORK IN A LUM/SAT/HUE REPRESENTATION

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Abstract The extension of lattice based operators to color images is still a challenging task in mathematical morphology. The first choice of a well-defined color space is crucial and we propose to work on a lum/sat/hue representation in norm L_1. We then introduce an unified framework to consider different ways of defining morphological color operators either using the classical formulation with total orderings by means of lexicographic cascades or developing new transformations which takes advantage of an adaptive combination of the chromatic and the achromatic (or the spectral and the spatio-geometric) components. More precisely, we prove that the presented saturation-controlled operators cope satisfactorily with the complexity of color images. Experimental results illustrate the performance and the potential applications of the new algorithms.

Keywords: color mathematical morphology, luminance/saturation/hue, lexicographic orderings, reconstruction, gradient, top-hat, leveling, segmentation

1. Introduction

Mathematical morphology is the application of lattice theory to spatial structures [16] (i.e. the definition of morphological operators needs a totally ordered complete lattice structure). Therefore the extension of mathematical morphology to color images is difficult due to the vectorial nature of the color data. Fundamental references to works which have formalized the vector morphology theory are [17] and [8].

Here we propose here a unified framework to consider different ways of defining morphological color operators in a luminance, saturation and hue color representation. This paper is a summary of the Ph. D. Thesis of the author [1] done under the supervision of Prof. Jean Serra (full details of the algorithms and many other examples can be found in [1]).

C. Ronse et al. (eds.), Mathematical Morphology: 40 Years On, 387–396.

2. Luminance/Saturation/Hue color in norm L_1

The primary question to deal with color images involves choosing a suitable color space representation for morphological processing. The RGB color representation has some drawbacks: components are strongly correlated, lack of human interpretation, non uniformity, etc. A polar representation with the variables luminance, saturation et hue (lum/sat/hue) allows us to solve these problems. The HLS system is the most popular lum/sat/hue triplet. In spite of its popularity, the HLS representation often yields unsatisfactory results, for quantitative processing at least, because its luminance and saturation expressions are not norms, so average values, or distances, are falsified. In addition, these two components are not independent, which is not appropriate for a vector decomposition. The reader can find a comprehensive analysis of this question by Serra [20]. The drawbacks of the HLS system can be overcome by various alternative representations, according to different norms used to define the luminance and the saturation. The L_1 norm system has already been introduced in [18] as follows:

$$\begin{cases} l = \frac{1}{3}(max + med + min) \\ s = \begin{cases} \frac{3}{2}(max - l) & if\ l \geq med \\ \frac{3}{2}(l - min) & if\ l \leq med \end{cases} \\ h = k\left[\lambda + \frac{1}{2} - (-1)^{\lambda}\left(\frac{max+min-2med}{2s}\right)\right] \end{cases} \tag{1}$$

where max, med and min refer the maximum, the median and the minimum of the RGB color point (r, g, b), k is the angle unit ($\pi/3$ for radians and 42 to work on 256 grey levels) and $\lambda = 0$, if $r > g \geq b$; 1, if $g \geq r > b$; 2, if $g > b \geq r$; 3, if $b \geq g > r$; 4, if $b > r \geq g$; 5, if $r \geq b > b$ allows to change to the color sector. In all processing that follows, the l, s and h components are always those of the system (1), named LSH representation.

3. Morphological color operators from LSH

For detailed exposition on complete lattice theory refer to [7]. Let $E, \mathcal{T}$ be nonempty set. We denote by $\mathcal{F}(E, \mathcal{T})$ the power set $\mathcal{T}^E$, i.e., the functions from E onto $\mathcal{T}$. If $\mathcal{T}$ is a complete lattice, then $\mathcal{F}(E, \mathcal{T})$ is a complete lattice too. Let f be a grey level image, $f : E \to \mathcal{T}$, in this case $\mathcal{T} = \{t_{min}, t_{min} + 1, \cdots, t_{max}\}$ is an ordered set of grey-levels. Given the three sets $\mathcal{T}^l, \mathcal{T}^s, \mathcal{T}^h$, we denote by $\mathcal{F}(E, [\mathcal{T}^l \otimes \mathcal{T}^s \otimes \mathcal{T}^h])$ or $\mathcal{F}(E, \mathcal{T}^{lsh})$ all color images in a LSH representation ($\mathcal{T}^{lsh}$ is the product of $\mathcal{T}^l, \mathcal{T}^s, \mathcal{T}^h$, i.e., $\mathbf{c}_i \in \mathcal{T}^{lsh} \Leftrightarrow \mathbf{c}_i = \{(l_i, s_i, h_i); l_i \in \mathcal{T}^l, s_i \in \mathcal{T}^s, h_i \in \mathcal{T}^h\}$). We denote the elements of $\mathcal{F}(E, \mathcal{T}^{lsh})$ by $\mathbf{f}$, where $\mathbf{f} = (f_L, f_S, f_H)$ are the color component functions. Using this representation, the value of $\mathbf{f}$ at a point $x \in E$, which lies in $\mathcal{T}^{lsh}$, is denoted by $\mathbf{f}(x) = (f_L(x), f_S(x), f_H(x))$. Note that the sets $\mathcal{T}^l, \mathcal{T}^s$ corresponding to the luminance and the saturation are complete totally