Color Image Enhancement Using the Support Fuzzification

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Abstract. Simple and efficient methods for image enhancement can be obtained through affine transforms, defined by the logarithmic operations. Generally, a single affine transform is calculated for the whole image. A better quality is possible to obtain if a fuzzy partition is defined on the image support and then, for each element of the partition an affine transform is determined. Finally the enhanced image is computed by summing up in a weight way the images obtained for the fuzzy partition elements.

1 Introduction

The logarithmic models have created a new environment for developing some new methods of image enhancement [1-3], [8]. The logarithmic model presented in this paper is the one developed in [3]. It uses a real and bounded set for gray levels and for colors. Within this structure, image enhancement methods are easily obtained by using an affine transform. Otherwise, such a solution is not sufficient in the case of images with variable brightness and contrast. Better results can be obtained if partitions are defined on the image support and then the pixels are separately processed in each window belonging to the defined partition. The classical partitions frequently lead to the appearance of some discontinuities at the boundaries between these windows. In order to avoid all these drawbacks the classical partitions may be replaced by fuzzy partitions. Their elements will be fuzzy windows and in each of them there will be defined an affine transform induced by parameters using the fuzzy mean and fuzzy variance computed for the pixels that belong (in fuzzy meaning) to the analyzed window. Their calculus uses logarithmical operations. The final image is obtained by summing up in a weight way the images of every fuzzy window as defined before. Within this merging operation, the weights used are membership degrees, which define the fuzzy partition of the image support. Further on, there will be presented the way this logarithmic model of image representation is built. Next, the definition of the fuzzy partition on the image support and then, the determination of the affine transforms for each component (window) of the partition. The last sections comprise experimental results and some conclusions.

2 The Fundamentals of the Logarithmic Model

Further on, there will be a short presentation of the vector space on the gray level set and then, for the vector space of the colors. More details concerning the notions in this section may be found in [3].

2.1 The Vector Space of Gray Levels

Let there be considered the space of gray levels as the set $E = (-1,1)$. In the set of gray levels the addition $\langle + \rangle$ and the multiplication $\langle \times \rangle$ by a real scalar will be defined and then, defining a scalar product $(\cdot | \cdot)_E$ and a norm $\|.\|_E$, a Euclidean space of gray levels will be obtained.

The Addition. The sum of two gray levels, $v_1 \langle + \rangle v_2$ will be defined by:

$$v_1 \langle + \rangle v_2 = \frac{v_1 + v_2}{1 + v_1 v_2}, \forall v_1, v_2 \in E \ . \tag{2.1.1}$$

The neutral element for the addition is $\theta = 0$. Each element $v \in E$ has an opposite $w = -v$. The subtraction operation $\langle - \rangle$ will be defined by:

$$v_1 \langle - \rangle v_2 = \frac{v_1 - v_2}{1 - v_1 v_2}, \forall v_1, v_2 \in E \ . \tag{2.1.2}$$

The Multiplication by a Scalar. The multiplication $\langle \times \rangle$ of a gray level v by a real scalar λ will be defined as:

$$\lambda \langle \times \rangle v = \frac{(1+v)^{\lambda} - (1-v)^{\lambda}}{(1+v)^{\lambda} + (1-v)^{\lambda}}, \forall v \in E, \forall \lambda \in R \ . \tag{2.1.3}$$

The above operations, the addition $\langle + \rangle$ and the scalar multiplication $\langle \times \rangle$ induce on E a real vector space structure.

The Fundamental Isomorphism. The vector space of gray levels $\left(E, \langle + \rangle, \langle \times \rangle\right)$ is isomorphic to the space of real numbers $(R, +, \cdot)$ by the function $\varphi : E \to R$, defined as:

$$\varphi(v) = \frac{1}{2} \ln\left(\frac{1+v}{1-v}\right), \forall v \in E \ . \tag{2.1.4}$$

The isomorphism φ verifies:

$$\varphi(v_1 \langle + \rangle v_2) = \varphi(v_1) + \varphi(v_2), \forall v_1, v_2 \in E \ . \tag{2.1.5}$$

$$\varphi(\lambda \langle \times \rangle v) = \lambda \cdot \varphi(v), \forall \lambda \in R, \forall v \in E \ . \tag{2.1.6}$$