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An adaptive fuzzy approach for modeling visual texture properties

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Abstract

The analysis of the perceptual properties of texture plays a fundamental role in tasks like semantic description of images, content-based image retrieval using linguistic queries, or expert systems design based on low level visual features. The presence of these properties in images is very difficult to characterize due to their imprecision, and, moreover, because their perception may change depending on the user or the image context. In this paper, texture properties are modeled by means of an adaptive fuzzy approach that takes into account the subjectivity of the human perception. For this purpose, a methodology in two phases has been proposed. First, non-adaptive fuzzy models, that represent the average human perception about the presence of the texture properties, are obtained. For this modeling, we propose to learn a relationship between representative measures of the properties and the assessments given by human subjects. In a second phase, the obtained fuzzy sets are adapted in order to model the particular perception of the properties that a user may have, as well as the changes in perception influenced by the image context. For this purpose, the membership functions are automatically transformed on the basic of the information given by the user or extracted from the image context, respectively.

Keywords: Fuzzy sets; Image processing; Texture modeling; Human perception; Adaptive models

1. Introduction

Color, texture, and shape are typically the three most used features for object recognition and image interpretation. Color and shape represent clear concepts for humans, and their importance is widely known in computer vision. Texture, however, is more imprecise and abstract but an equally important feature. In spite of its importance, there

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(a) (b) (c)

Fig. 1. Examples showing the imprecision associated to the properties.

is not an accurate definition for the concept of texture, but some widespread intuitive ideas. Texture is described by some authors as local changes in the intensity patterns or gray tones, which is used in opposition to the homogeneity idea [1]. Other authors consider texture as a set of basic items called *texels* (or texture primitives), arranged in a certain way. However, for humans, the most common way to describe texture is by using vague textural properties, like *coarseness*, *directionality*, *contrast*, *line-likeness* or *regularity* [2,3], that are a more natural way to represent our perception about texture primitives. Coarseness is related to the spatial size of texels, directionality reflects whether they have a dominant orientation, contrast is related to their distinguishability, line-likeness reflects whether they have straight shapes, and regularity refers to the variation of their placement. From all of them, and according to the psychological experiments performed by Tamura et al. in [3], coarseness, contrast and directionality are considered the three most important texture properties, playing a fundamental role in human visual interpretation [4–6]. In this paper, we will focus our study on these properties.

Computational models with the ability of providing a perceptual texture characterization on the basis of these properties can be very useful in tasks where some interaction with subjects is needed. For example, they can be applied in fields such as semantic description of images [7–9], obtaining texture descriptions that are directly interpretable by humans, or in content-based image retrieval systems [10,11,4], where linguistic queries related to the degree to which texture properties are present can be employed.[1] In addition, this perceptual characterization of texture can be also applied in expert systems, where the information provided by the expert is related to the presence of the texture properties. For example, suppose a medical expert that, according to his/her experience, concludes that the regions with high fineness presence and high contrast degree in microscopic images are indicative of a certain disease. Models that are able to provide a textural description in a similar way as humans would can be employed to automatically identify these areas in the images.

However, there are two main problems related to the modeling of the perceptual properties of texture. The first one is the imprecision associated to them. This imprecision must be understood in the sense that, except in extreme cases, we cannot set a precise threshold between textures that strictly accomplish a property and textures that do not, but the fulfillment of the property is gradual in nature. For example, we can reasonably say that the texture shown in Fig. 1(a) is coarse and contrasted, and that the texture shown in Fig. 1(c) is not, as they represent potential extreme cases for both properties. However, the fulfillment of these properties is not so clear for the texture shown in Fig. 1(b).

This way, it is natural for humans to give assessments about the degree to which these perceptual properties are present. For example, if a subject is asked about the degree of the coarseness presence in the images of Fig. 1, this subject would probably say that the texture shown in Fig. 1(a) is very coarse, the texture shown in Fig. 1(b) has an intermediate coarseness degree, or the texture shown in Fig. 1(c) is very fine. Likewise, if the subject is asked about the degree of the contrast presence, these textures may be perceived with a high degree, low degree and very low degree of this property, respectively.

The second main drawback related to the modeling of texture properties is the subjectivity associated to their perception. On the one hand, the perception of a texture property may change depending on the user. For example, although we have considered that the texture shown in Fig. 1(a) is very coarse, another user may consider

[1] Notice that the aim in this case is not to retrieve images with a similar texture as a whole (like in classical texture analysis approaches in the literature), but to retrieve images with a similar degree of presence in certain, required texture properties.