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Perception-based fuzzy partitions for visual texture modeling

Pedro Manuel Martínez-Jiménez [a,*], Jesús Chamorro-Martínez [a], José Manuel Soto-Hidalgo [b]

[a] *Department of Computer Science and Artificial Intelligence, University of Granada, C/Periodista Daniel Saucedo Aranda s/n, 18071 Granada, Spain*

[b] *Department of Computer Architecture, Electronics and Electronic Technology, University of Córdoba, Campus Universitario de Rabanales, 14071 Córdoba, Spain*

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Abstract

Visual textures in images are usually described by humans using linguistic terms related to their perceptual properties, like "very coarse", "low directional", or "high contrasted". Computational models with the ability of providing a perceptual texture characterization on the basis of these terms can be very useful in tasks like semantic description of images, content-based image retrieval using linguistic queries, or expert systems design based on low level visual features. In this paper, we address the problem of simulating the human perception of texture, obtaining linguistic labels to describe it in natural language. For this modeling, fuzzy partitions defined on the domain of some of the most representative measures of each property are employed. In order to define the fuzzy partitions, the number of linguistic labels and the parameters of the membership functions are calculated taking into account the relationship between the computational values given by the measures and the human perception of the corresponding property. The performance of each fuzzy partition is analyzed and tested using the human assessments, and a ranking of measures is obtained according to their ability to represent the perception of the property, allowing to identify the most suitable measure.

Keywords: Image analysis; Feature extraction; Texture modeling; Fuzzy partitions; Linguistic labels; Human perception

1. Introduction

Color, texture, and shape are typically the three most used low level 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 is not an accurate definition for the concept of texture, but some widespread intuitive ideas. Texture is described by some authors, in opposition to the idea of homogeneity, as local changes in the intensity patterns or gray tones [1]. Other authors consider texture as a set of basic items called *texels* (or texture primitives), arranged in a certain way.

* Corresponding author.
E-mail addresses: pedromartinez@decsai.ugr.es (P.M. Martínez-Jiménez), jesus@decsai.ugr.es (J. Chamorro-Martínez), jmsoto@uco.es (J.M. Soto-Hidalgo).

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(a) (b) (c)

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

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 addition, it is natural for humans to give linguistic terms to describe the presence degree of these perceptual properties. For example, if a subject is asked about the presence degree of coarseness 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) is "coarse", or the texture shown in Fig. 1(c) is "very fine". Likewise, if the subject is asked about the presence degree of contrast, these textures may be perceived as "high contrasted", "medium contrasted" and "very low contrasted", respectively.

Computational models that are able to provide such kind of linguistic terms can be very useful in tasks where the most relevant information of the image lies in the presence degree of the perceptual properties of texture. In this type of tasks some interaction with subjects is usually needed, so models that describe texture as humans would are particularly interesting. For example, these models can be applied in fields such as semantic description of images [7–9], or in content-based image retrieval systems [10,11,4]. In this case, linguistic queries related to the presence degree of texture properties can be employed. In addition, the proposed models 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 very fine and high contrasted texture in microscopic images are indicative of a certain disease. Models that are able to provide a textural description as expert would can be employed to automatically identify these areas in the images.

In this paper, we propose a perception-based fuzzy approach where each texture property will be modeled by means of a fuzzy partition defined on the domain of representative measures of the corresponding property. Because of the importance of coarseness, contrast and directionality concepts, we will focus our study on these perceptual properties (although other texture properties such as regularity, line-likeness, etc. can be easily dealt with in a similar way). In order to select the number of fuzzy sets in our partition, we analyze the ability of each measure to discriminate between different categories of the perceptual property. For this purpose, a distinguishability analysis will be applied to each measure on the basis of the human perception of the texture property. To get information about the human perception, a set of images covering different presence degrees of the properties will be used to collect, by means of polls, human assessments from a set of subjects. This way, we propose to set the number of linguistic labels used in our approach as the number of different presence degrees of the property that the measure can actually discriminate. Moreover, we propose to obtain the membership function associated to each fuzzy set by using the information given by the distinguishability analysis, obtaining a fuzzy partition adapted to the human perception of the property. This way, the presence degrees associated to the linguistic labels will match what a human would expect, providing intuitive and very useful results, as it will be shown in section 8. In addition, goodness measures are proposed in order to identify the most appropriate models to represent the properties of coarseness, contrast and directionality.

The rest of the paper is organized as follows. Section 2 describes the related work in the literature, while in section 3 a general overview of our methodology is presented, introducing some basic concepts and the notation used in the

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