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A fuzzy approach for modelling visual texture properties

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ABSTRACT

In this paper, we address the problem of simulating the human perception of texture properties in images. In particular, we have focused our study on the properties of coarseness, contrast and directionality, that play a fundamental role in the human perception of texture. The objective is not to precisely identify, classify or discriminate between different textures as a whole, but to be able to assess the presence of each texture property in the image. For this purpose, fuzzy sets defined on the domain of different groups of measures are employed in order to model each property by using parametric membership functions. The corresponding parameters are obtained by learning a functional relationship between the computational values given by the measures and the human perception. The performance of each fuzzy set is analyzed and tested with the human assessments, and a ranking of subsets of measures is obtained according to their ability to represent the perception of the property, allowing us to identify the most suitable combination of measures.

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 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 [50]. 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* [48,59], that are a more naturally 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 [59], coarseness, contrast and directionality are considered the three most important texture properties, playing a fundamental role in human visual interpretation [35,36,41]. We will focus our study on these properties in this paper.

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One of the main problems related to texture description is the imprecision associated to these perceptual properties. 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 accomplishment 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(d) is not, as they represent potential extreme cases for both properties. However, the accomplishment of these properties is not so clear for the textures shown in Fig. 1(b) and (c).

This way, it is natural for humans to give assessments about 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(c) has an intermediate coarseness degree, or the texture shown in Fig. 1(d) is very fine. Likewise, if the subject is asked about the presence degree of contrast, these textures may be perceived with a high degree, low degree and very low degree of this property, respectively.

Taking into account this perceptual interpretation of texture, the main objective of this paper is to obtain models that are able to represent the presence degree of the textural properties in a similar way as humans would. For this purpose, we propose to model the properties of coarseness, contrast and directionality (although other properties can be easily dealt with in a similar way) by means of fuzzy sets defined on the domain of representative measures of these properties. In our approach, subsets of computational measures are used as reference set, which allows to combine the ability of different measures to capture the presence of the property. In order to obtain the membership function associated to each fuzzy set, a functional relationship between the computational values given by the measures and the human perception of the property is learned. This way, the presence degree given by the obtained fuzzy set will match what a human would expect. In addition, our approach allows us to identify the most suitable combination of measures to represent the corresponding property.

To the best of our knowledge, there are no approaches in the literature that are able to provide this kind of information. At this point, we would like to emphasize that, nowadays, the majority of the image analysis techniques in computer vision try to model texture by means of feature vectors (that usually have very large dimensions), which have no direct relationship with the different perceptual properties. These techniques are used to identify, classify, or discriminate between different textures by comparing their feature vectors, but they cannot capture the presence of a certain particular property in the image. Although our approach can be also employed to identify, classify, or discriminate between different textures, our main objective is to assess the presence of the perceptual properties. For example, let us consider the four images shown in Fig. 2. We can clearly see that these images are very different regarding their textures. However, if we take into account only the presence degree of coarseness, the four textures can be considered as "very coarse" according to this property.

Models that are able to provide such kind of information 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 in a similar way as humans would are particularly interesting. For example, these models can be applied in fields such as semantic description of images [8,38,42], or in content-based image retrieval systems [3,17,35]. In this case, linguistic queries related to the presence degree of texture properties can be employed. Note that, as it was commented above, the aim is not to retrieve images with a similar texture as a whole, but to retrieve images with a similar presence degree in certain, required texture properties. In addition, the proposed models

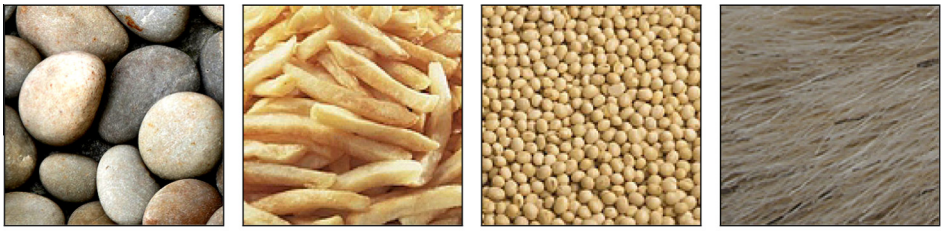

Fig. 1. Examples showing the imprecision associated to the properties.

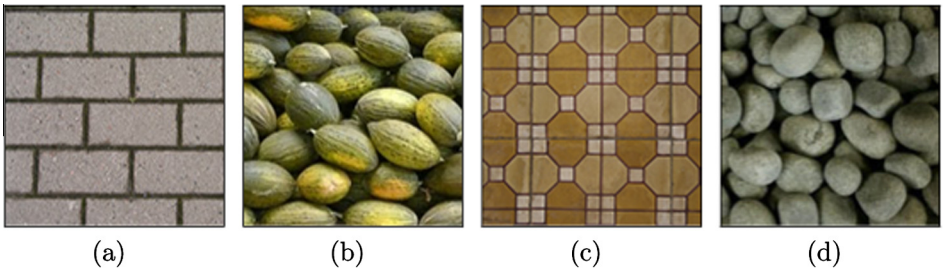

Fig. 2. Examples of textures that can be considered as "very coarse".