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DETERMINING THE SOLUTION SPACE FORM FOR AN INDETERMINATE PATTERN RECOGNITION PROBLEM. THE "SKIN DETECTION" CASE

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Abstract: *This paper presents some methods regarding how to gain more efficiency when selecting skin in digital images. Selecting skin is of great concern as a prior step – if it is not a final problem - before accomplishing other tasks that operate "inside" skin regions e.g. red eyes reduction, face detection, facial features analysis etc. Even if we treat the specific problem of determining efficiently the skin locus, the method described here could be generalized for other indeterminate pattern recognition problems. The challenge is to perform a "maximal" extraction from the input data – this includes the conditions of the images/photos acquisition and the camera settings – and to provide an adaptive and dynamic framework in order to update and upgrade the method with eventual new useful input information. This flexibility plus the two major igredients of efficiency in industry, accuracy and speed, plus the state of the art will configure a more efficient method to determine the space solution form for a less indeterminate pattern recognition problem.*

Key words: *Indeterminate Problem, Pattern Recognition, Color Image Processing, Skin Detection, Face Detection*

1. INTRODUCTION

As is stated in a review article (Kakumanu et al., 2006): "skin detection plays an important role in a wide range of image processing applications ranging from face detection, face tracking, gesture analysis, content-based image retrieval systems and to various human computer interaction domains. Recently, skin detection methodologies based on skin-color information as a cue has gained much attention as skin-color provides computationally effective yet, robust information against rotations, scaling and partial occlusions." Our goal is to find the most "generous" framework for the skin detection problem. That is, our method aims at allowing for an easy and efficient (plug and play) addition of any new criteria (e.g. motion or some neighbourhood criteria as skin texture and skin prototypes, or some edge features as the contours for the faces or eyes) proven to increase the selectiveness of the method. By design, with each update the method reduces the false negatives. We think that a dynamic pixel-based approach is the optimal one in terms of robustness and modularity. We remind that a pixel-based method classifies each pixel as skin or non-skin individually, independently from its neighbours; in contrast, a *region-based* method tries to take spatial arrangement of skin pixels into account to enhance the method performance (Chang & Zhiqiang, 2007).

A digital (CCD) color camera can be described as a filter that transforms continuous color signals to three components (red, green and blue), every component having a value in a limited range. This spectral data compression generates metamerism: they appear as two different colors under a certain illuminant, whereas under a second illuminant they cannot be discriminated. In general, the non-linearity of the camera is caused by the input-output conversion in which the transformation and its parameters depend on the input signal. Although in color image formation the main factors are the illuminant, the spectral power distribution, the spectral sensitivities of the camera and surface reflectances, there are many other factors which can have an essential effect: scene and acquisition geometry (shadows), surroundings, camera settings, camera type and other non-idealities of the camera. All these real aspects conduct us to a more experimental data-centric approaching, rather than to an approaching aiming to deduce mathematical equations, by which we could delimitate the solution space. We, as other researchers, experienced the fact that such an approaching is a more realistic one than trying to catch in explicit formulas the skin locus.

Skin detection has a long history, and, in the last decade, some surveys and comparisons of different techniques were published. The method we proposed is a mixture of the state of the art methods, trying to mix the best aspects of these methods from an industry oriented point of view. Building a system for skin detection, we meet three main problems (Vezhnevets et al., 2003):

1. what color space to choose
2. how exactly the skin color distribution should be modelled
3. the algorithm for the skin filter

In our paper we report 1., 2. and mention 3.

2. CHOOSING THE COLOR SPACE AND COLLECTING SKIN PIXELS

The common sense suggests that human skin appearance in photos is more controlled by the chrominance coordinates than the luminance one: the luminance could vary in a much larger interval than the chrominance. Many works on skin detection drop the luminance component of the color space. The dimensionality reduction, achieved by discarding luminance also simplifies the consequent processing. Anyway, we know that the explicit separation between luminance and chrominance is an important step on the way of determining the space solution for our skin detection problem. Another observation is that skin appears to have a predominance of red and non-blue (exceptional cases are florescent illuminated scenes with bluish faces, but, in general, let us note that the Cr component would deserve a higher "resolution" in a skin pixel representation). Given also the RGB ↔ YCbCr transformation simplicity and the "popularity" of the YCbCr color space, we have a strong recommendation to choose YCbCr as our working color space. In fact this color space was used very often in skin pixel classification (Gonzales & al. 2010). YCgCr, a variant of YcbCr, was reported to "produce" a more compact locus of skin pixels (deDios & Garcia, 2003). This color space uses the smallest color difference (G-Y) instead of (B-Y) - as transmission oriented spaces use in order to minimize the encoding-decoding errors - and it is defined exclusively for analysis applications, mainly for face segmentation. Anyway, choosing YCbCr or YCgCr color space could not change significantly the considerations in this paper. The real requirements of the specific application will prove that this choice is better.

The faces, the eyes bands and the mouth bands were marked in the database photos. We collected skin pixels from faces, after removing these bands and after putting thresholds on a cumulative histogram in order to ignore the pixels with extreme luminance. We retained all the information for a skin pixel - Y, Cb, Cr and the number of occurrences of this pixel - and represented all the collected pixels:

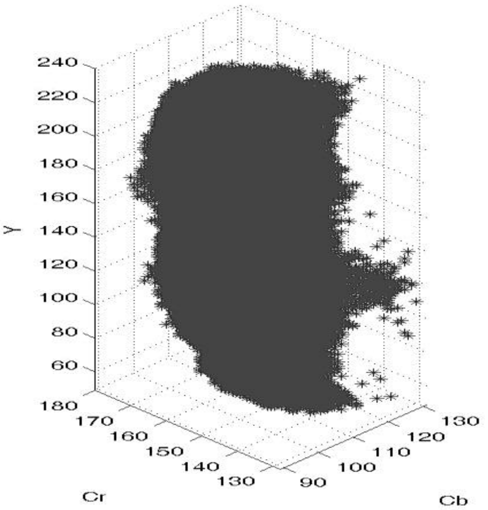

Fig. 1. The 3D representation of the skin locus (without the probability information)

It is important to keep in mind that we worked with a large (the larger, the better) database with images. A database is assigned for each set of conditions: the conditions of the images acquisition, the camera type and the camera settings, ethnicity and so on… the more parameters, the less indetermination. In an initial stage, we collect skin locus information. This initial information could be refined in a separate stage.

3. SKIN LOCUS FORM

It is the moment to gain a lot of efficiency: we observe that the 3D representation of the skin locus has a great resemblance with a cylinder. We will retain for each [Cb][Cr] skin pixel the number of occurrences of this pixel. For Y component we will retain a low and a high global threshold. The skin locus has a 2D representation:

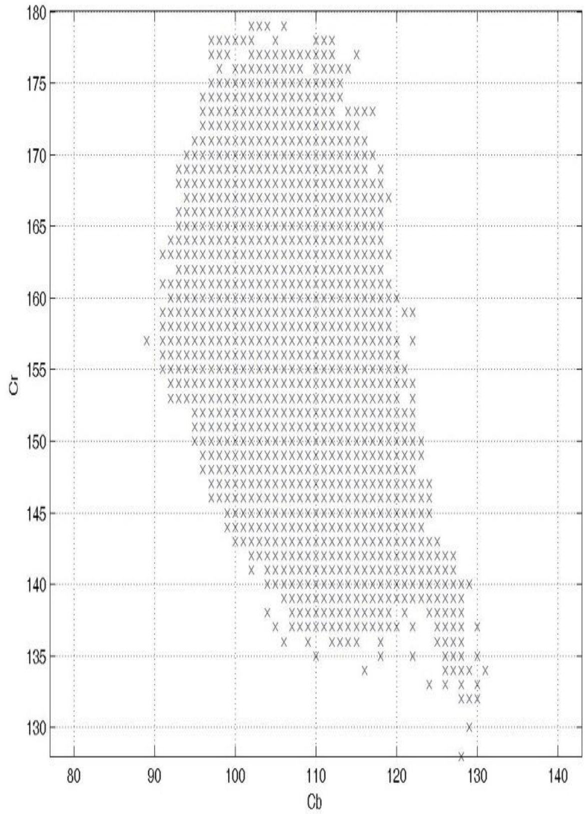

Fig. 2. The CrCb skin locus representation

Other observations resulted:

1. On a face there are many different pixels and, in general, we need various rather than many situations in the database: Cb and Cr intervals for 20 photos were almost the Cb and Cr intervals for 883 photos (the 20 ones are in the 883 ones). Let us note the interpolation possibility with fewer data.
2. A confirmed intuition: the skin locus grows concentrically, in center being the pixels with the highest probability i.e. number of occurrences.

Further, in order to gain more efficiency, we can compact more the skin locus by morphological operations based on probability information.

4. CONCLUSION

We designed an experimental approaching which is optimized to value all the significant information that could be extracted from the database with calibration images. The further work - in order to implement skin detection - could be done separately, using the data collected as described above.

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