SELF ORGANIZING NEURAL NETWORK APPLICATION FOR SKIN COLOR SEGMENTATION

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Abstract: In this paper, we present a Fuzzy ART (Adaptive Resonance Theory) neural network application for skin color segmentation using the chromaticity components of the TSL color space. The Fuzzy ART networks deal with the stability-plasticity dilemma and they can be applied to color image segmentation, particularly to skin color segmentation. The developed application has three modes: parameter setting, skin color filter creation, and skin color filter performance. Many parameters can be tuned to create proper skin color filters from manually selected skin regions in an image. A skin color filter is a LUT (Look-Up Table) that gives each color in the RGB color space, one of two different outputs, skin or non-skin color. The performance of different skin color filters can be compared with the application. A skin color filter can be used to make robust real-time skin color segmentation in video sequences captured by a webcam.

1 INTRODUCTION

Many computer vision applications such as surveillance and access control systems, person identification and Human-Computer Interfaces (HCI) require the detection, localization, and tracking of human body parts. These tasks in a complex computer vision application stress the importance of a low processing time as real-time working is usually a constraint in the global application. Moreover, reliable computer vision applications need robustness to changes in illumination, background, and objects of interest.

In this context, color is widely used for the detection and tracking of human body parts as it is robust to geometric changes and fast to calculate. Phung et al. (2005) presented an analysis of three important issues for the skin color segmentation: color representation, color quantization, and classification algorithm. Schmugge et al. (2007) studied the performance of five color space transformations with and without the luminosity component for skin segmentation.

In this paper, we present a novel application to make skin color filters from the chromaticity components of the TSL color space of the pixels within manually selected skin regions in an image. A skin color filter is a LUT so that every color in the RGB color space is tagged as skin or non-skin color. The application to create the LUT is based on a Fuzzy ART neural network (Carpenter et al., 1991). This is a self organizing neural network characterized for being stable and plastic and it is suitable for color image segmentation. The created skin color filter can be used to make skin color segmentation in video sequences captured by an inexpensive Universal Serial Bus camera robustly to changes in illumination and motion of the human body parts in an unrestricted environment.

The rest of the paper is organized as follows. In Section 2, we present the literature regarding skin color filtering and the TSL color space, whose chromaticity components are used to characterized skin regions in images. Section 3 deals with the Fuzzy ART neural network and the reasons why we use it to classify skin colors. Next, the skin color filter application is presented in Section 4 along with its three working modes: parameter setting, skin color filter creation, and skin color filter performance. Finally, Section 5 draws the conclusions about the developed skin color application.

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2 SKIN COLOR SEGMENTATION

Color filtering is a powerful tool in computer vision tasks. It is a low level feature, highly discriminative, computationally fast, and robust to geometric changes that can be applied in the definition of human body parts. Many studies evaluating color spaces for skin detection have been carried out (Kakumanu et al., 2007; Phung et al., 2005). Color can be decomposed into three different components, one luminosity and two chromaticity components. Although skin color can notably change from some human being to other or even in the same human being due to factors such as a suntan, a blush, etc., several researches have proved that skin colors have a certain invariance regarding chromaticity components, although skin colors belong to people of different ethnic groups (Fu Jie Huang and Tsuhan Chen, 2000). Other factors such as lighting or skin tone affect mainly the luminosity component.

Different color spaces separating luminosity and chromaticity components have been used for skin color segmentation (YIQ, CIE-LAB, CIE-LUV, HSV, HIS, and TSL) (Kakumanu et al., 2007; Phung et al., 2005). TSL has been selected as the best color space to extract skin color from complex backgrounds (Chen and Liu, 2003) because it has the advantage of extracting a given color robustly while minimizing illumination influence.

In our application, the chromaticity components of the TSL color space are used to create skin color filter.

3 FUZZY ART NEURAL NETWORKS

The ART neural network architecture is a self-organizing network that allows to switch between a learning or plastic state (in which the network parameters may be modified) and a stable or fixed state for operation (Carpenter and Grossberg, 1987). Fuzzy ART is an extension of the ART1 system (Carpenter et al., 1991) that allows analog inputs with values between 0 and 1. The most important point in the application of an ART network to color image segmentation, and especially skin color segmentation, is the stability-plasticity dilemma. The ART network has plasticity in order to learn new information, while it has stability in order not to forget the already learned information. ART networks are able to obtain stability without sacrificing plasticity (Carpenter and Grossberg, 1987).

In our application, a Fuzzy ART neural network is used to categorize each color as skin or non-skin.

4 SKIN COLOR FILTER APPLICATION

We have developed a skin color filter application so that a filter, which classifies every color as being skin color or not, is created from skin regions of an image manually selected by the user. A Fuzzy ART neural network is used to create the skin color filter. The inputs to the neural network are the chromaticity components (T and S) of the TSL color space of all the pixels inside the skin region of an image. The TSL color space was selected as it achieved the best skin color filtering performance in an experimental study including the normalized rgb, YIQ, HIS, CIELUV, and TSL space (González-Ortega et al., 2010).

The application has been developed using the Intel Open Source Computer Vision Library (Open Computer Vision Library, 2010) and the FLTK GUI Library (FLTK Library, 2010). The application has three working modes: 1) parameter setting, 2) skin color filter creation, 3) skin color filter performance.

4.1 Parameter Setting

The application allows to select a series of parameters that influence skin color filter creation. The parameters are grouped in four sets: preprocessing, histogram setting, Fuzzy ART neural network setting, and skin color filter setting. Default values of the parameters were fixed after many experimental results. These values lead to a good performance with images taken with different conditions regarding the webcam, the illumination, and user.

The main preprocessing parameters are cr, cg, and cb. They fix the contribution of each component in the luminosity calculation of each pixel.

The histogram setting allows to specify whether a selected skin region is too bright, bright, normal, dark, or too dark.

The main parameters of the Fuzzy ART neural network setting are:

- Num_rounds: number of times that the selected region is introduced in the neural network. Default value is 2.
- Rho1: vigilance parameter of the network in the training stage. Values closed to 0 imply fewer

categories because the network groups with little strict similarity criteria. Values closed to 1 imply more categories, each one with very similar patterns. Default value is 0.9.

- Rho2: vigilance parameter of the network in the testing stage. Values closed to 0 imply little strict similarity criteria. Values closed to 1 make the patterns be very similar to the created categories to be included within them. Default value is 0.9.

The main parameters in the skin color filter creation are:

- beta: percentage of the patterns that a category has to exceed with respect to the patterns in the category with the largest number of colors so that the category can be considered skin color category. Default value is 0.02.
- delta: percentage of patterns that the category with the largest number of colors classified by the Fuzzy ART network has to exceed. Large values of delta imply that the regions have to be very homogeneous regarding color. Default value is 0.05.
- epsilon: upper limit of the Euclidean distance between a category and the biggest category so that the category can be considered in the classification process of the colors. Large values of epsilon imply that the category can be more separated so that more different categories are taken into account. Default value is 0.2.
- mu: contribution of the saturation component of the TSL color space in the Euclidean distance calculation among categories. Default value is 1.

After selecting the values of all the parameters, a file can be saved with this information so that these values can then be used in the filter creation.

4.2 Skin Color Filter Creation

In this mode, a frame of a video sequence captured by a webcam can be selected. In this frame, the skin regions have to be manually selected. With the computer mouse, the user selects the vertexes of the polygonal region that determine each skin region in the image. If some regions are selected within other previously selected region, the interior regions will be excluded from the exterior region. This is interesting if the user wants to select the face excluding the eyes, lips, or beard. To begin the process of creating a skin filter, a parameter configuration file has to be selected. With the values that appear in this file and the selected region, the Fuzzy ART neural network is trained.

The patterns used to train the network are the chromaticity components (T and S) of the pixels in the selected region because they can characterize skin color optimally as explained in Section 2.

In the training process, the categories will be committed as the chromaticity components of the selected region be introduced in the Fuzzy ART neural network a number of times specified by num_rounds. After the training stage, a series of committed categories that fulfill the rules fixed by the parameters are associated with the skin color characterized by the selected region. In the testing stage, all the possible values of the chromaticity components are introduced to the trained network.

From the RGB color space, 8 bits are used to represent each color coordinate, so that there are 2^{3x8}=16,777,216 colors. Each color in the RGB space is converted to the TSL space. Each pair of T and S values are introduced to the trained network so that it is considered skin color (with all the possible values of L) if it is assigned a committed skin color category. From the testing of all the 16,777,216 colors in the RGB color space, a LUT is created to give each color one of two different outputs, skin or non-skin color. Thus, the created LUT can be used to make real-time skin segmentation in videos captured by a webcam. For each LUT (skin color filter), the application saves in a log file the information regarding the skin filter creation including configuration parameters, the number of pixels used to train the network, the number of created categories, and the number of skin colors.

4.3 Skin Color Filter Performance

The application allows to compare the performance of two skin color filters applied to the same video. Fig. 1 shows the result of two different filters. The pixels that are not colored (yellow on the left part and green on the right part) are the ones that the corresponding skin filter categorized as skin. The left image is the result of using a filter created with rho1=0.95 and rho2=0.9. The right image is the result of using a filter created with rho1=0.9 and rho2=0.9. The remaining parameters for creating both filters were the default values. The bigger rho1 is, the more categories Fuzzy ART generates. This way, with rho1=0.9, 12 categories were generated and with rho1=0.95, 26 categories were generated. It can be observed in Fig. 1 that rho1=0.9 gives rise to a better skin segmentation.

Although skin color detection is good in both images, with rho1=0.95 the larger number of created categories causes that a significant part of the image that does not correspond to skin is incorrectly segmented as skin, giving rise to an incorrect image segmentation.

Fig. 2 shows the results of using two filters that differ in the beta parameter used in their creation (left image with beta =0.1 and right image with beta=0.02). The remaining parameters for creating both filters were the default values. In the video, the background has some colors similar to skin color, so that the more restricted value of beta (0.1) gives rise to a better segmentation because the incorrect categorization of background colors as skin color is greatly reduced. In contrast, there is a small portion of the face that is not categorized as skin due to the bright caused by the illumination. This bright facial region is better categorized by the filter with a less restricted value of beta (0.02).

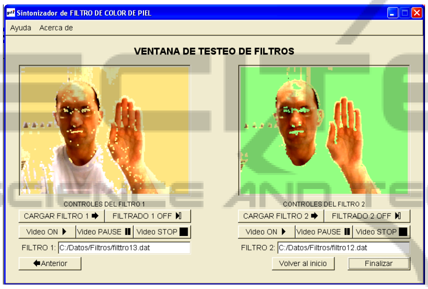

Figure 1: Skin color filter comparison.

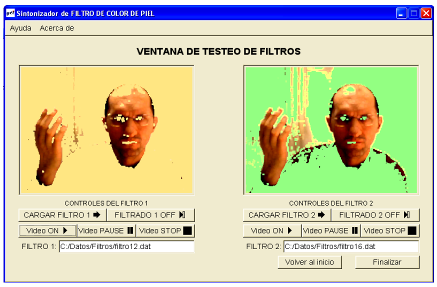

Figure 2: Skin color filter comparison.

5 CONCLUSIONS

In this paper, a novel skin color filter application based on Fuzzy ART neural network is presented. From the chromaticity components of the TSL color space of the pixels belonging to skin regions in an image, a Fuzzy ART neural network is trained. All the colors are then categorized by the neural network as belonging to skin or not. Finally, a LUT is created by assigning one out of two different outputs, skin or non-skin color to all the colors in the RGB color space.

Although the skin colors present certain invariance regarding chromaticity components, changes in the illumination, camera or the motion of the human body parts can have a significant impact on skin color appearance. Even though the presented application can be used to manually selected skin regions, it can be adapted so that after an initial face or hands detection in an image from a video sequence, the optimal skin color filter can be created for the tracking of the skin regions in successive frames of the video sequence.

A created skin color filter makes real-time tracking robust to changes in illumination and appearance in videos taken in a non-controlled environment. The developed application allows to create skin color filter to make robust human body parts monitoring.

REFERENCES

Carpenter, G.A. and Grossberg, S. (1987). A massively parallel architecture for a self-organizing neural pattern recognition machine. *Computer Vision, Graphics and Image Processing (CVGIP)*, 37(1): 54–115.

Carpenter, G.A., Grossberg, S., Rosen, D.B. (1991). Fuzzy ART: Fast stable learning and categorization of analog patterns by an adaptive resonance system. *Neural Networks*, 4(6): 759–771.

Chen, D., Liu, Z. (2003). A novel approach to detect and correct highlighted face region in color image. In: *Proceedings of the IEEE conference on advanced video and signal based surveillance*, 7–12.

FLTK Library. http://www.fltk.org. 2010.

Fu Jie Huang, Tsuhan Chen (2000). Tracking of multiple faces for human-computer interfaces and virtual environments. In: *Proceedings of the IEEE International Conference on Multimedia and Expo 2000*, Vol. 3, 1563–1566.

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Kakumanu P., Makrogiannis S., Bourbakis N. (2007). A survey of skin-color modeling and detection methods. *Pattern Recognition*, 40(3), 1106–1122.

Open Computer Vision Library. http://sourceforge.net/projects/opencvlibrary. 2010.

Phung S.L., Bouzerdoum A., Sr., Chai D., Sr. (2005). Skin segmentation using color pixel classification: analysis and comparison. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 27(1): 148–154.

Schmugge, S.J., Adeel Zaffar, M., Tsap. L.V., Shin, M.C. (2007). Task-based evaluation of skin detection for communication and perceptual interfaces. *Journal of Visual Communication and Image Representation*, 18(6), 487–495.