Facial image segmentation based on mixed colour space.

S. Anishenko[1], D. Shaposhnikov[1]
R. Comley[2], X. Gao[2]

[1] *A.B.Kogan Research Institute for Neurocybernetics, Southern Federal University, Rostov-on-Don, Russia, sergey.anishenko@gmail.com*

[2] *School of Engineering and Information Sciences, Middlesex University, London, NW4 4BT, UK, x.gao@mdx.ac.uk*

Abstract—A facial image segmentation algorithm which employs mixed colour space is presented. Mixed colour space is used for skin colour pixel modelling and "colour" edge detection. "Colour" edge densities are used for classification of detected regions of interest (ROI's). Attributes for mixed colour space are chosen from different spaces based on a training dataset of video sequences. It is shown that a facial image is segmented without any false negative regions however false positive regions are still present.

1. Introduction

Facial image segmentation is a common task used for many different purposes in computer vision, e.g. non-invasive human-computer interaction, head motion detection and pose estimation all require a solution to the problem of facial image segmentation [1]. Many algorithms have been developed to perform segmentation, and can fall into two major groups.

The first group is based on modelling of facial shape and appearance. Shape can vary due to differences between persons and changes in head position, facial expression and camera viewpoint [4]. The first group of algorithms therefore depend on head position and facial expression. The second group of algorithms are based on skin colours [2]. Colour information has been used to detect skin on an image in order to segment a head from the rest of the scene. However, skin colour can vary widely under different illumination conditions, so use of colour alone in the detection of facial skin is not sufficient. Other information is necessary to verify selected ROI's such as a face. Colour is useful as a pre-processing step because it may significantly reduce the number of candidates.

The primary aim of this work is to evaluate relevant colour spaces that are attributed to model skin colour under different illumination levels and a wide range of head poses. The second aim is to choose suitable features for ROI classification leading to the development and evaluation of a facial image segmentation algorithm.

2. Image collection

A set of video sequences (n=9) with known illumination conditions and distances between the camera and subjects has been collected to evaluate colour space attributes (Fig. 2). Illumination levels are 6.4 Kd/m (Fig. 2.1), 1.4 Kd/m (Fig. 2.2), 2.4 Kd/m (Fig. 2.3). Under each illumination condition three frames (n=90) were captured (Fig. 2.a, 2.b, 2.c). The distance between the subject's head and the camera is equal to 1.08m. Before shooting, the cameras were calibrated as detailed in [1].

The position of a subject's head on an image is similar to the head position during a PET scanning procedure [3]. Video images have been captured using two off-the-shelf digital cameras, a Fujifilm and Sony. In this work only videos taken using the Fujifilm camera are applied as training datasets.

In order to evaluate the developed algorithms for facial image segmentation two video sequences with unknown varying illumination levels and head pose have been collected using a web-camera (Fig. 1.1) and the Fujifilm camera (Fig. 1.2). The scale and head pose are totally different from training image set.

Figure 1. An example of testing video frames.

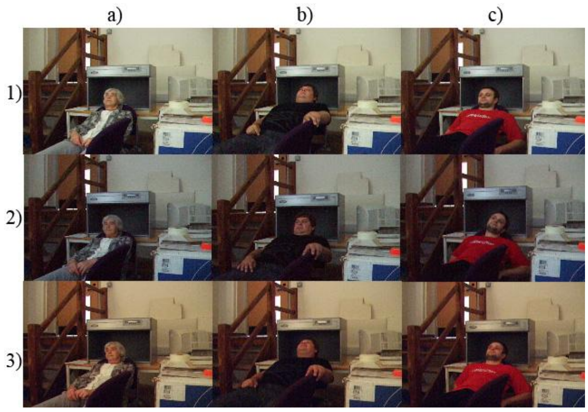

Figure 2. An example of training video frames.

3. Colour space evaluation

Many colour spaces with various properties have been developed for different purposes including computer graphics, colorimetry, data transmission and storing. Several of them have been applied to the problem of skin colour modelling, which will be described in detail in the next sections.

3.1 Colour spaces used for skin modelling

RGB

RGB (red, green, and blue) is one of the most popular colour spaces for storing digital image data. The colour of a pixel in an image is described using three mixed rays, red (R), green (G) and blue (B). RGB is a popular colour space for image segmentation because no transformation is needed [11] as most colour display devices (e.g., a colour monitor, a TV) use RGB to represent a colour image.

HSV, HSL

However popular it is, RGB colour space is device dependent, i.e., the same colour will appear differently on different colour monitors, which causes inaccuracy when it comes to image processing based on RGB. Therefore other colour spaces are introduced. HSL and HSV are perceptual colour spaces. Hue represents the actual colour or tint information, whereas the “lightness” or “value” is related to the colour luminance.
The intuitiveness (i.e. close to human perception) of the colour space components and explicit discrimination between luminance and chrominance properties made these colour spaces popular in the works on skin colour segmentation [2].

CIEXYZ

To standardise colour spaces, the International Commission on Illumination (CIE from the French name *Commission internationale de l'éclairage*) has introduced several spaces for different applications.
In 1931, the CIE defined the CIE*XYZ* colour space (also known as the tristimulus colour space) which is relative to the standard observer and therefore, each colour can be represented by three values of X, Y, and Z. Terrillon et al. showed that CIEXY (normalized CIEXYZ) were most efficient for skin segmentation because the skin chromaticities occupied a smaller area in them [8].

CIELAB, CIELUV

For measurement of colour difference the colour spaces CIELAB and CIELUV were proposed by G. Wyszecki and standardized by CIE. Colours in the CIELAB space are perceptually more uniformly spaced than are colours in the RGB or HSV spaces [12], enabling the use of a fixed colour distance in decision making over a wide range of colours. Another perceptually uniformed colour space is the CIELUV space, which can be used for this purpose as well [10, 12].

CIECAM02

Since these CIE colour spaces are defined under fixed viewing conditions, i.e. D50 or D65 with fixed surroundings, they don’t account for the differences in colour appearance induced by the change of viewing environment. A human vision model was therefore developed by CIE to predict the colour appearance under a wide range of viewing conditions, which is called the colour appearance model and is based on colour vision theories. CIECAM02 can predict a colour as accurate as an average observer. This space is useful for segmentation of facial images captured under low level and varying illumination conditions [3].

In this study all aforementioned (n=7) colour spaces are evaluated to model skin colour under varying lighting conditions.

3.2 Colour elements for skin modelling

A facial area on each frame of the training video sequences (see sec. 2) was marked up by hand. Frames were then represented using seven colour models/spaces, as described above. The histograms of each colour element for each colour space/model was calculated in the facial area (Fig. 3).

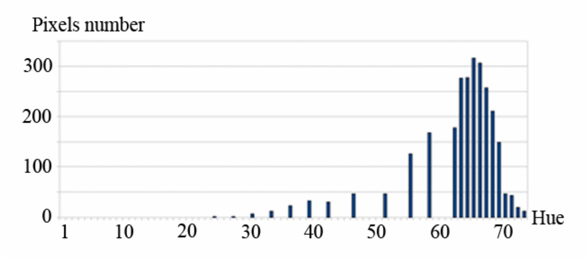

Figure 3. An example Hue (HLS) histogram in the face area.

The maximum peak of the histogram was chosen as a skin colour attribute. Then the average value of each skin colour attribute was calculated independently for three training video sequences taken under varying viewing conditions. Five colour attributes with the minimum difference between skin colour attribute values under different lighting condition were chosen to model skin colours (Table 1).

Illumination / Colour	1	2	3
Hue (HLS)	10.8±2.6	6.2±1.8	7.3±1.5
Achromatic response (CIECAM02)	26.5±3	23±2.7	24.4±2.9
Chroma (CIECAM02)	16±2.3	14.4±2.3	23.2±2.7
Colourfulness (CIECAM02)	11.9±1.7	10.6±1.6	16.7±2
Saturation (CIECAM02)	28.1±3.3	27.2±3.4	34.1±3.8

Table 1.

3.3 ROI verification

After colour segmentation, a detected ROI needs to be verified. As shown in the tests, a useful clue for verification is “colour” edges. In our work the Sobel operator is used to detect “colour” edges on all the frames (Fig. 4.3). By studying the edge density in facial areas, we conclude that an area should be classified as a face if:

$$0.15<Q<0.5$$

where Q is the brightness in CIECAM02.

4. Facial image segmentation

An algorithm for facial image segmentation based on mixed colour space has been developed and tested. To detect a skin colour pixel the mixed colour spaces are used. The pixel is classified as skin if:

$3 < H < 13$ and
$18 < A < 28$ and
$15 < M\text{-}S < 18$ and
$10 < C\text{-}S < 13$,

where H is Hue (HLS), A is Achromatic response (CIECAM02), C is Chroma (CIECAM02), M is Colourfulness (CIECAM02), S is Saturation (CIECAM02). After the classification of skin colour pixels (Fig. 4.1), the marked pixels are grouped together into regions of interest using the nearest neighbourhood method (Fig. 4.2), arriving at a segmented ROI.

After colour segmentation an ROI is classified based on information on “colour” edge densities inside ones (Fig. 4.4).

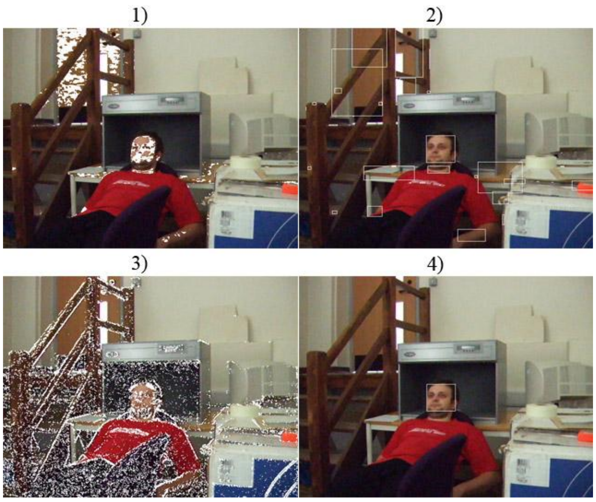

Figure 4. Steps in the facial image segmentation algorithm. 1 – detected skin colour pixels, 2 – segmented areas, 3 – detected colour edges, 4 – verified areas.

The result of the computer simulation of facial segmentation is presented in the Table 2.

Table 2. List of results on the segmentation of faces.

Example of video Result	Fig 2.1	Fig 2.2	Fig 2.3	Fig 1.1	Fig 1.2
Segmented (%)	100	100	100	100	100
False positive regions (%)	240	206.7	302	23	3.3
False positive regions before verifying (%)	3781	3059	3565	1524	440
False negative region (%)	0	0	0	0	11
False negative region before verifying (%)	0	0	0	0	0

Table 2.

5. Summary

In our study a new approach to perform facial image segmentation based on skin colour is presented. A group of colour elements for modelling of skin pixels is chosen based on three video sequences captured under certain lighting conditions. It is shown that based on the chosen attributes a facial image can be segmented with few false negative regions.

Also a new approach to classify an ROI in images such as a face based on “colour” edge densities is presented.

A future step is to improve the described algorithm by adding a step to perform ROI classification more precisely. The developed software is also needs to be optimized in order to perform real time segmentation of video frames.

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6. References

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