Real Time Image Segmentation for Face Detection Based on Fuzzy Logic

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ABSTRACT:

The segmentation of objects whose color-composition is not trivial represents a difficult task. In this work we propose a fuzzy algorithm application for the segmentation of such objects. It is chosen; by the characteristics that it represents the face segmentation. A priori knowledge about spectral information for certain face skin region classes is used in order to classify image in fuzzy logic classification procedure.

The basic idea was to perform the classification procedure first in the supervised and then in fuzzy logic manner. Some information, needed for membership function definition, was taken from supervised maximum likelihood classification. The system uses three membership functions which are taken as Gaussian distribution curve. For real time needs, the system is implemented on an FPGA.

Keywords: skin segmentation, Fuzzy logic, Fuzzy implementation.

1 INTRODUCTION

Skin detection enables a wide range of machine vision tasks such as the detection, tracking and recognition of face and gesture, which are required for human-machine interaction [1]. Most of these tasks are required to be implemented in real time. Skin detection is typically achieved using color information [2][3][4], which is a feature that can be computationally inexpensive and thus well suited for such real-time applications. A number of algorithms have been proposed to achieve color based skin detection, including statistical methods, neural networks or template matching.

An important step in the image classification process is color segmentation of the image into homogeneous skin color regions and non-skin color regions in color space that is relatively invariant to minor luminance changes. The segmentation is used to localize and identify homogeneous regions in a picture by perceptual attributes which include the size, the shape and the texture and/or color information. This operation is necessary for any manipulation of analysis of image by computer, understanding and interpretation. After segmenting out skin from images, this can be useful for identifying faces, hand sign recognition, offensive content such pornography[5]

Peer et al.[6] presented a simple skin classifier through a number of rules. This method have attracted many researchers [7][8][9]. The main difficulty achieving high recognition rates with this method is the need to find both good color space and adequate decision rules empirically. Machine learning algorithms to find both suitable color space and a simple decision rule that achieve high recognition rates [10]

We address in this paper a digital techniques coupled with parallel processing potential of fuzzy logic for segmentation of skin in colored images. A hybrid adaptive system which combined the advantages of knowledge based and fuzzy methods is proposed. *Pixel*(*c*|*skin*) and *Pixel*(*c*|¬*skin*) are directly computed from the proposed system in real time.

2 SEGMENTATION USING FUZZY LOGIC

Fuzzy image processing is not a unique theory. It is a collection of different fuzzy approaches to image processing[11]. Nevertheless, the following definition can be regarded as an attempt to determine the boundaries: Fuzzy image processing is the collection of all approaches that understand, represent and process the images, their segments and features as fuzzy sets. The representation and processing depend on the selected fuzzy technique and on the problem to be solved. Fuzzy image processing has three main stages: image fuzzification, modification of membership values*, and, if necessary, image defuzzification (see Fig.1.).

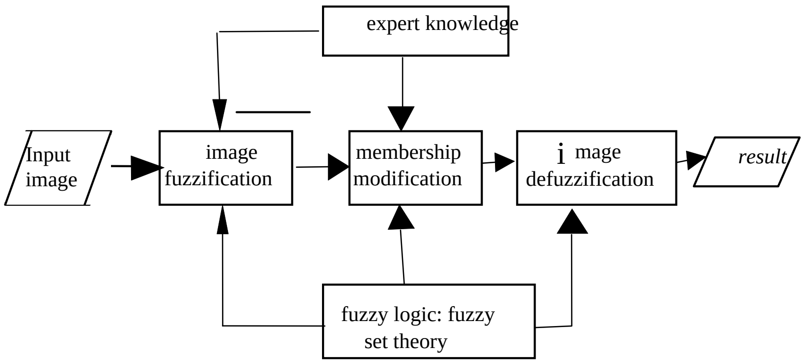

Fig. 1. The general structure of fuzzy image processing

*** In this paper the membership function has been fixed after the training session by large number of skin and non-skin samples, so the modification stage is not used.**

The different theoretical components of fuzzy image processing provide us with diverse possibilities for development of new segmentation techniques. The following points give a brief overview of different fuzzy approaches to image segmentation[11][12]:

1. <u>Fuzzy Clustering</u>: Algorithms Fuzzy clustering is the oldest fuzzy approach to image segmentation. Algorithms such as fuzzy c-means (FCM) can be used to build clusters (segments). The class membership of pixels can be interpreted as similarity or compatibility with an ideal object or a certain property.

2. <u>Fuzzy Rule-Based Approach</u>: If we interpret the image features as linguistic variables, then we can use fuzzy if-then rules to segment the image into different regions. A simple fuzzy segmentation rule may seem as follows: IF the pixel is dark AND its neighbourhood is also dark AND homogeneous THEN it belongs to the background.

3. <u>Fuzzy Integrals</u>: Fuzzy integrals can be used in different forms: Segmentation by weightening the features (fuzzy measures represent the importance of particular features). Fusion of the results of different segmentation algorithms (optimal use of individual advantages). Segmentation by fusion of different sensors (e.g. multi spectral images, fuzzy measures represent the relevance/importance of each sensor).

4. <u>Measures of Fuzziness and image information</u>: Measures of fuzziness (e.g. fuzzy entropy) and image information (e.g. fuzzy divergence) can be also used in segmentation and thresholding tasks. For example, a membership function (standard S function) is moved pixel by pixel over the existing range of gray levels. In each position, a measure of fuzziness is calcultaed. The position with a minimum amount of fuzziness can be regarded as a suitable threshold.

5. <u>Fuzzy Geometry</u>:

Fuzzy geometrical measures such as fuzzy compactness and index of area coverage can be used to measure the geometrical fuzziness of different regions of an image. The optimization of these measures (e.g. minimization of fuzzy compactness regarding to the cross-over point of membership function) can be applied to make fuzzy and/or crisp pixel classifications.

In this paper we focus on extracting some natural features from images working at pixel level. A *priori* knowledge about pixel information for certain skin classes is used in order to classify an image in fuzzy logic manner. More specifically, the membership functions are defined using results from supervised classification. Among the mentioned fuzzy segmentation approaches, the system is more likely to be belong to the 2nd approach.

3 COLOR MODELS FOR SKIN COLOR CLASSIFICATION

The study on skin color classification has gained increasing attention in recent years due to the active research in content-based image representation. For instance, the ability to locate image object as a face can be exploited for image coding, editing, indexing or other user interactivity purposes. Moreover, face localization also provides a good stepping stone in facial expression studies. It would be fair to say that the most popular algorithm to face localization is the use of color information, whereby estimating areas with skin color is often the first vital step of such strategy. Hence, skin color classification has become an important task. Much of the research in skin color based face localization and detection is based on RGB, YCbCr and HSI color spaces. In this section the color spaces are being described.

3.1 RGB Color Space

The RGB color space[13] consists of the three additive primaries: red, green and blue. Spectral components of these colors combine additively to produce a resultant color. The RGB model is represented by a 3-dimensional cube with red green and blue at the corners on each axis (Fig 2). Black is at the origin. White is at the opposite end of the cube. The gray scale follows the line from black to white. In a 24-bit color graphics system with 8 bits per color channel, red is (255, 0, 0). On the color cube, it is (1, 0, 0). The RGB model simplifies the design of computer graphics systems but is not ideal for all applications. The red, green and blue color components are highly correlated. This makes it difficult to execute some image processing algorithms. Many processing techniques, such as histogram equalization, work on the intensity component of an image only.

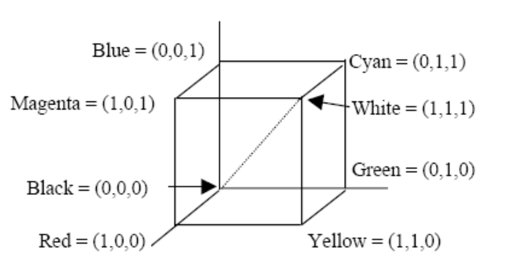

Fig. 2. RGB color cube

3.2 YCbCr Color Space

YCbCr color space[13] has been defined in response to increasing demands for digital algorithms in handling video information, and has since become a widely used model in a digital video. It belongs to the family of television transmission color spaces. The family includes others such as YUV and YIQ. YCbCr is a digital color system, while YUV and YIQ are analog spaces for the respective PAL and NTSC systems. These color spaces separate RGB (Red-Green-Blue) into luminance and chrominance information and are useful in compression applications however the specification of colors is somewhat unintuitive. The recommendation 601 specifies 8 bit (i.e. 0 to 255) coding of YCbCr, whereby the luminance component Y has an excursion of 219 and an offset of +16. This coding places black at code 16 and white at code 235. In doing so, it reserves the extremes of the range for signal processing footroom and headroom. On the other hand, the chrominance components Cb and Cr have excursions of +112 and offset of +128, producing a range from 16 to 240 inclusively.

3.3 HSI Color Space

Since hue, saturation and intensity are three properties used to describe color, it seems logical that there be a corresponding color model, HSI[13]. When using the HSI color space, you don't need to know what percentage of blue or green is required to produce a color. You simply adjust the hue to get the color you wish. To change a deep red to pink, adjust the saturation. To make it darker or lighter, alter the intensity. Many applications use the HSI color model.

Machine vision uses HSI color space in identifying the color of different objects. Image processing applications such as histogram operations, intensity transformations and convolutions operate only on an intensity image. These operations are performed with much ease on an image in the HIS color space. For the HSI being modeled with cylindrical coordinates, see Fig. 3. The hue (*H*) is represented as the angle 0, varying from 0^o to 360^o. Saturation (*S*) corresponds to the radius, varying from 0 to 1. Intensity (*I*) varies along the *z* axis with 0 being black and 1 being white. When $S = 0$, color is a gray value of intensity 1. When $S = 1$, color is on the boundary of top cone base. The greater the saturation, the farther the color is from white/gray/black (depending on the intensity). Adjusting the hue will vary the color from red at 0^o, through green at 120o, blue at 240^o, and back to red at 360^o. When $I = 0$, the color is black and therefore H is undefined. When $S = 0$, the color is grayscale. H is also undefined in this case. By adjusting I, a color can be made darker or lighter. By maintaining $S = 1$ and adjusting I, shades of that color are created.

Other representations where color and intensity are represented independently are YUV and YQQ color spaces. The color plane in Yuv forms an equilateral triangle that can be constructed in the RGB cube by connecting its R,G, and B corner. The intensity Y is perpendicular to the image plane. The value U and V are the Cartesian coordinated of the color value. The value for Y , U and V are calculated as $Y=(R+G+B)/3$, $U=3(R-B)/2Y$, and $V=\sqrt{3}(2G-R-B)/2Y$

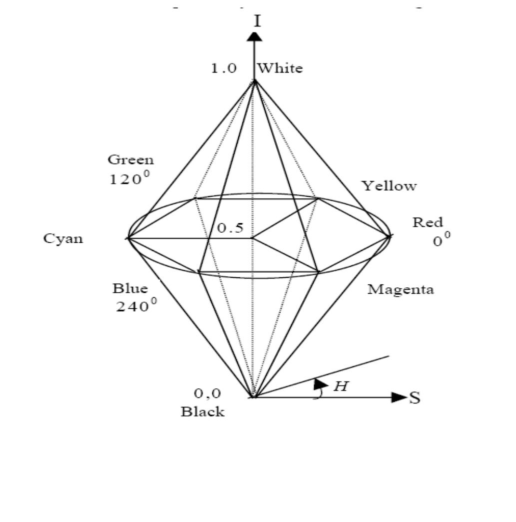

Fig. 3. Double cone model of HSI color space

A similar effect of intensity independence can be achieved by simply calculating *color ratios* $Q_{RG}=R/(R+G)$ and $Q_{RB}=R/(R+B)$. This color representation is referred to as YQQ space.

4 FUZZYSEGMENTATION SYSTEM

4.1 Fuzzy inference system (FIS)

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The process of fuzzy inference involves: *membership functions*, *fuzzy logic operators* and *if-then rules*. There are two types of fuzzy inference systems that can be implemented in the MATLAB Fuzzy Logic Toolbox[14]:

Mamdani-type and
Sugeno-type.

Mamdani's fuzzy inference method is the most commonly seen fuzzy methodology and it expects the output membership functions to be fuzzy sets. After the aggregation process, there is a fuzzy set for each output variable that needs defuzzification. Sugeno-type systems can be used to model any inference system in which the output membership functions are either linear or constant. This fuzzy inference system was introduced in 1985 and also is called Takagi-Sugeno-Kang. Sugeno output membership functions (z, in the following equation) are either linear or constant. A typical rule in a Sugeno fuzzy model has the following form:

If Input1 = x *and Input2* = y, *then Output is* z = ax + by + c

For a zero-order Sugeno model, the output level z is a constant *(i.e., a=b =0).*

4.2 Membership function

The membership functions used in this work are built as *Gaussian* shape function. Gaussian membership function is a fuzzy membership function that is often used to represent a vague, linguistic term which is given by (see Fig. 4):

where c_i and σ_i are the centre and width of the ith fuzzy set A^i, respectively.

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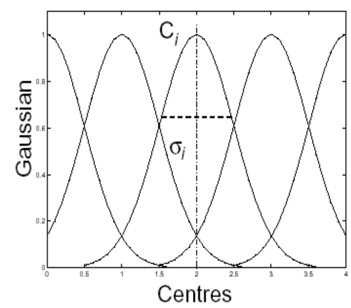

Fig.4. The Gausian membership shape

be abstracted as followes:
• local although not strictly compact

•

$$\mu_{A^i}(x) = \exp\left(-\frac{(c_i - x)^2}{2\sigma_i^2}\right) \qquad (1)$$

the output is very smooth
• not probability
• Multivariate Gaussian functions can be formed from the product of the univariate sets.
• Gaussian fuzzy membership functions are quite popular in the fuzzy logic literature, as they are the basis for the connection between fuzzy systems and radial basis function (RBF) neural networks.

4.3 Fuzzy logic operators

The most important thing to realize about fuzzy logical reasoning is the fact that it is a superset of standard Boolean logic. In other words, if the fuzzy values are kept at their extremes of 1 (completely true) and 0 (completely false), standard logical operations will hold. That is, A AND M operator is replaced with minimum - *min* (A,M) operator, A OR M with maximum - *max* (A,M) and NOT M with 1-M.

4.4 If-Then rules

Fuzzy sets and fuzzy operators are the subjects and verbs of fuzzy logic. Usually the knowledge involved in fuzzy reasoning is expressed as rules in the form:

If x is A Then y is B

where x and y are fuzzy variables and A and B are fuzzy values. The if-part of the rule "*x* is *A*" is called the *antecedent* or premise, while the then-part of the rule "*y* is *B*" is called the *consequent* or conclusion. Statements in the antecedent (or consequent) parts of the rules may well involve fuzzy logical connectives such as 'AND' and 'OR'. In the if-then rule, the word "is" gets used in two entirely different ways depending on whether it appears in the antecedent or the consequent part.

4.5 Segmentation procedure

The block diagram of the proposed fuzzy system is illustrated in Fig. 5.

Fuzzy logic controller (FLC) has been designed and implemented on an FPGA using VHDL. FLC consists of set of pipelined parts such as Fuzzification which transforms the input in degree of membership with linguistic values. The Inference Engine part performs the inference operations on the Rule Base. Finally, a Defuzzification transforms the fuzzy result of the inference process in a crisp output.

The implementation specifications of the FLC are: No. of input variables=3 (represent the color space components such as RGB, HSV, YCbCr, YQQ or YUV). No. of output variables=2(skin='1', non-skin='0'). No. of bits per each input variable=8. No. of bits per output variable =1. The types of membership function inputs and output are Gaussian and singleton respectively. Each input has single Gaussian membership function with a range of 255 values and the output has two singleton membership functions. XYZ fuzzy system is shown in Fig. 6(where X,Y and Z can be R,G and B or H,S and V, or other values for different color representations).

In this paper, *Gaussian* membership function needs two parameters for the valid definition: *mean* and *standard deviation* values. Values are given in Table 1 (mean value and standard deviation for each color space component of skin class). These values are used as the pattern (parameters) in FIS membership function design. Forty four images of 150x150 pixels are used as training samples to gather the information shown in table 1.

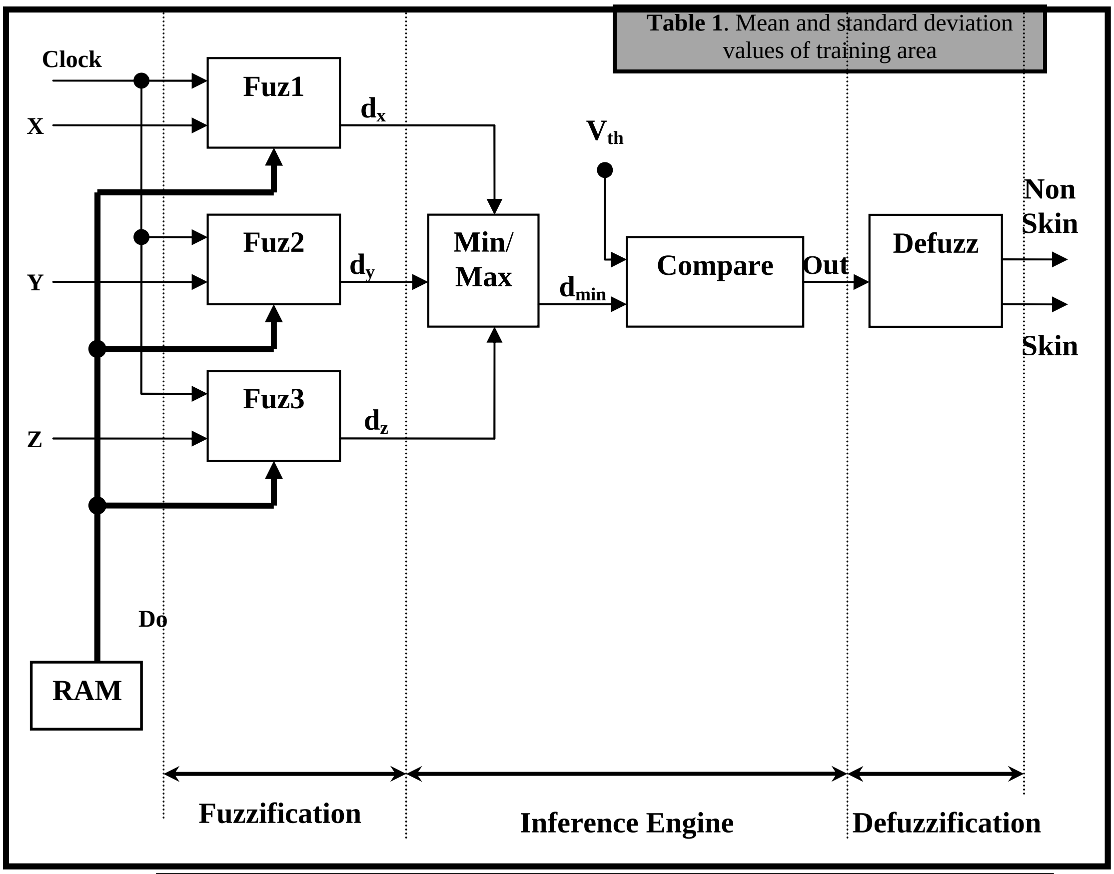

Fig.5: Block Diagram of Fuzzy System

Table 1. Mean and standard deviation values of training area

color representation ion	Mean(C)	st. deviation (α)
R	181.7287	39.2681
G	131.1352	37.7230
B	99.1087	38.5960
H	0.0671	0.0519
S	0.4665	0.1367
V	0.7127	0.1540
Y	138.4798	31.9222
Cb	106.4589	7.0774
Cr	152.5000	7.8528
Y	137.3242	36.9447
Q	0.5850	0.0342
Q	0.6574	0.0599
Y	137.3242	36.9447
u	0.9704	0.3799
v	-0.1270	0.1456

As shown in Fig. 6, fuzzification stage is designed using three components fuzzifier for each input which are connected with FPGA block RAM(s). The Gaussian membership function is implemented as a lookup table*. The input is assigned to the 8-bit value address of the BRAM, then, membership degree for the certain input in that location of RAM is given. The next step is Min component which compares the

***Using matlab, Membership's degree for each input is computed by applying Gaussian equation (eq. 1) and multiplying fuzzy values with a resolution of 8-bit:**

New Values = (2^n-1) × Fuzzy Value = (2^8-1) ×Fuzzy Value =255 × Fuzzy Value

Then, transforming the input's values with its degree to Hexadecimal representing in 8-bit by using the matlab function Dec2Hex (x). Finally, storing the Matlab's Hex values of the input with its computed degree as a look-up table in RAMB_S9_S18 FPGA RAM.

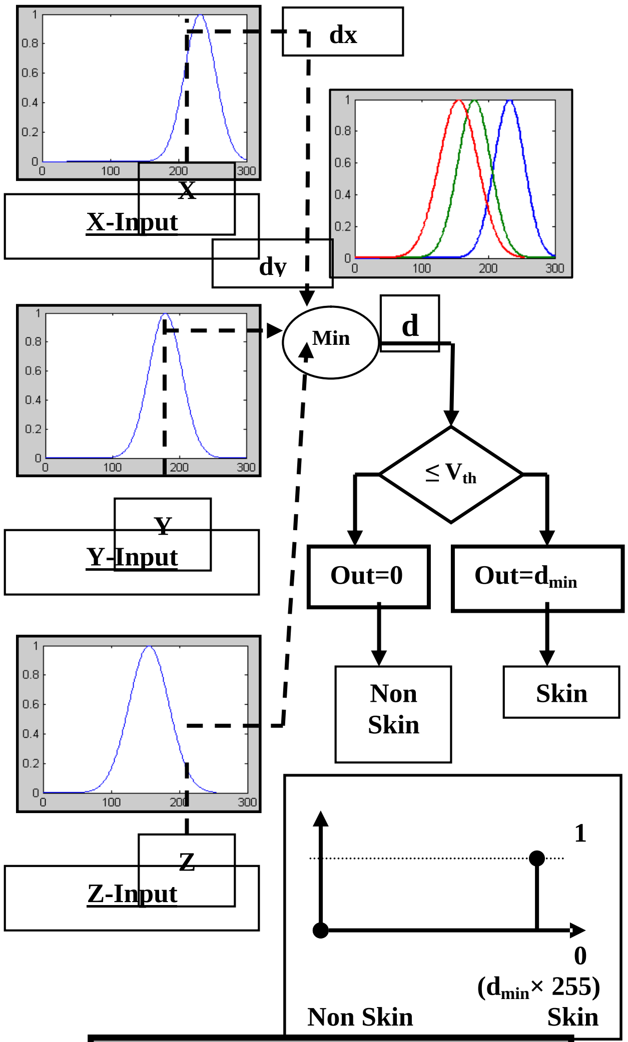

Fig (6):XYZ Fuzzy System

degrees of the inputs and output to find the minimum value. Then, the output of the minimum value is thresholded*. If degree is less than the threshold, output will assign to zero; otherwise the fuzzy output will be the minimum degree. The last step is defuzzifier which transforms the fuzzy output into crisp value (0 or 1).

5 RESULTS

The color segmentation system mentioned in previous sections have been applied to detect and to localize the human face in colored images in real time. In this paper an FPGA VLSI architecture that implements the segmentation network is proposed. Xilinx Spartan-3E FPGA of 500,000 gates is used for implementation. The FPGA digital hardware model has been designed using Xilinx Foundation environment.

Table 2 presents the utilization summary of the Spartan-3E(XC3S500E) chip when the word length is set to 16 bits. The FPGA resources shown in this table are exploited from all units of the designed architecture shown in Fig. 5.

Table 2: Utilization summary in RGB for Fuzzy System in the selected device Spartan 3E(XC3S500E)

Component	Number	utilization%
Slices	20 out of 4656	0%
Flip Flops	17 out of 9312	0%
4 input LUTs	35 out of 9312	6%
GCLKs	1 out of 24	15%
BRAMs	3 out of 20	4%

In Table 3, the utilization summary of selected device when using different color representations is shown. It can be seen that, the HSV consumes larger slices than YCbCr, but with fewer number of multipliers. On the other hand, RGB color representation can be used directly without any pre-calculation, but with losses in segmented image quality.

Table 3: Utilized components for different color space representation in the selected device Spartan-3E(XC3S500E) of 4656 slices and 20 embedded multipliers

Color space	RGB	HSV	YCbCr	YQQ	Y
slices	0	359	19	426	3
multipliers	0	1	8	0	

Fig. 7 shows the timing diagram of the **Minimum component (stage2)** in Fuzzy System shown in Fig. 5. As we can see in Fig. 7, the system requires **2 clks** to compute the output of this stage. Fig.8 shows the timing diagram of the Fuzzy System shown in

*** Threshold value can be selected manually (trail and error), or by using the fuzzy entropy value, where the threshold is calculated so that the entropy in the image is minimized.**

Fig. 5. As we can see in Fig. 8, the system requires **3 clks** to output the **final defuzzified result**. The **Model Sim XE III 6.0a** had been used to find the timing diagram for the stages of the fuzzy system.

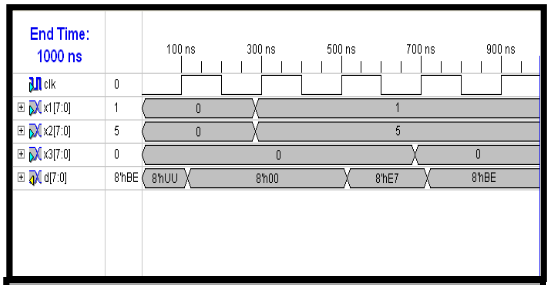

Fig. 7: The result of Minimum component

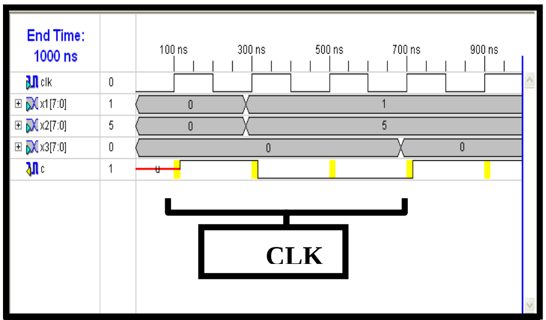

Fig. 8: The result of Defuzz component (stage3) in Fuzzy System

Fig. 9 shows the effectiveness of the color space representations for the classification of pixels when the threshold is set to zero.

6 CONCLUSION

As it can be seen from Fig.9, in the fuzzy clustering method, the results depend on the selected color space representation. When using the RGB representation, the clusters are not optimal and the regions are not usually homogeneous. When using other representation, the areas are more homogeneous and more compact. The best result can be seen when using HSV and YCbCr color space. In these two cases, although that the pixel is not thresholded (threshod is set to zero), the original image is reasonably segmented. There is no need to process the entire segmented image to select the threshold automatically (such as using fuzzy entropy). Therefore the time that required to produce the segmented image is greatly reserved. In RGB representation, a suitable threshold is urgently required. The calculation of such threshold value consumes long time which is unpractical in real time systems.

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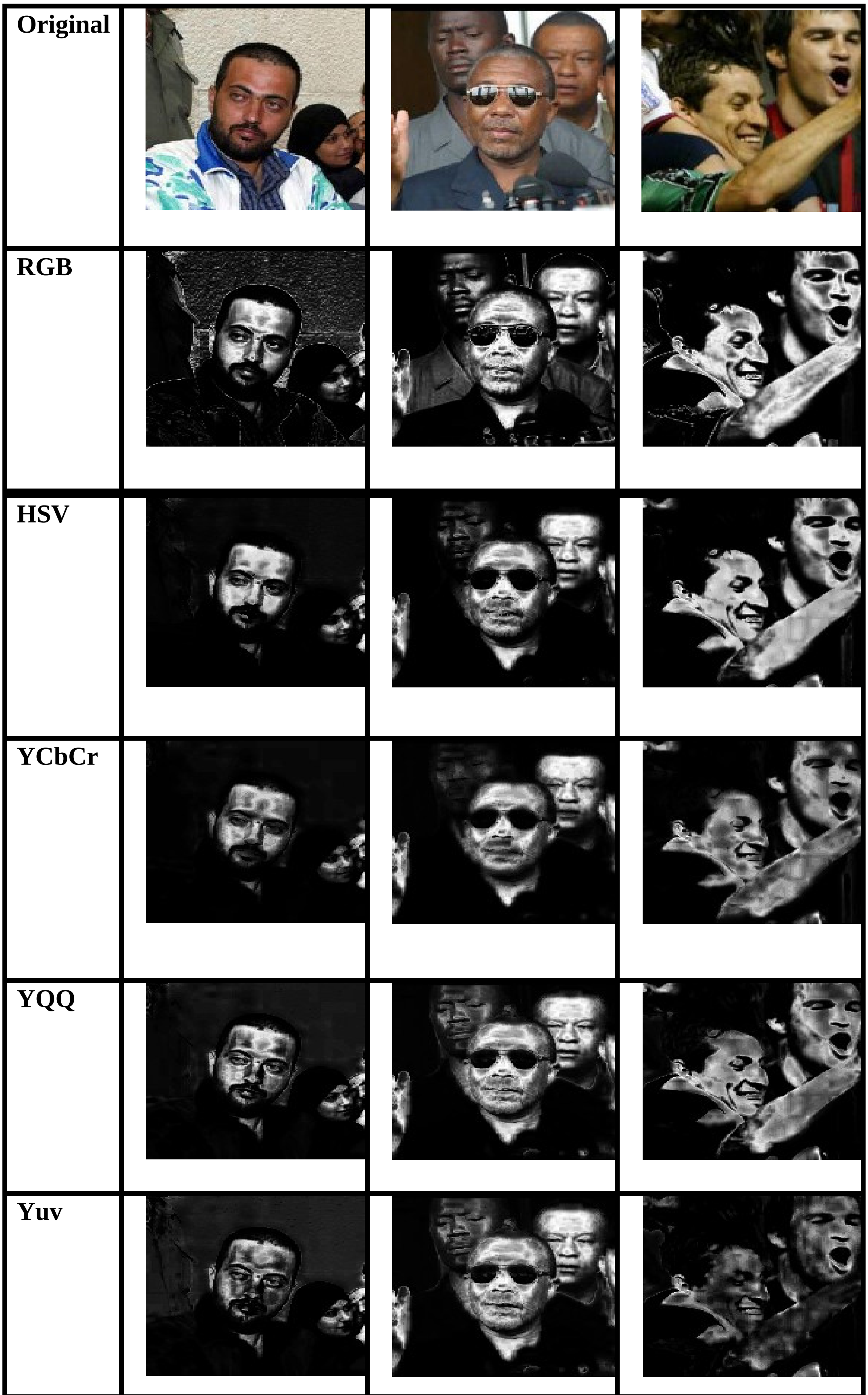

Fig.9: Skin-segmented images showing the effectiveness of segmentation approach under various color space representations.

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منظومة تقطيع الصورة في الزمن الحقيقي لكشف الوجوه باستخدام المنطق المضبب

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المستخلص:إن عملية تقطيع الأشياء التي تمتلك تركيبة الوان غير ضئيلة مهمة صعبة. في هذا العمل تم اقتراح خوارزمية مضببة لتطبيقها في عملية تقطيع مثل هكذا اشياء. تم اختيار تقطيع الوجوه لامتيازها بصفة الاشياء المذكورة آنفا.تستلزم عملية تصنيف الصورة باستخدام المنطق المضبب معرفة مسبقة حول طيف معلومات اصناف الجلد الموجودة في منطقة الوجه. الفكرة الاساسية هي انجاز عملية التصنبف اولا باستخدام مشرف و من ثم باستخدام المنطق المضبب. تم اخذ بعض المعلومات اللازمة لتعريف دالة الانتماء باستخدام التشابه الأقصى بوجود مشرف. يستخدم النظام ثلاثة دوال انتماء مبنية على اساس منحني توزيع كاوس. لاغراض تطبيقات الزمن الحقيقي. تم تنفيذ المنظومة بمصفوفة البوابات المبرمجة حقليا.