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Optimized Fuzzy System to Segment Colour Images

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ABSTRACT

Segmentation is one of the most important pre-processing steps towards pattern recognition and image understanding. In this paper novel colour image segmentation is proposed and implemented using fuzzy inference system. This system, which is designed by neuro-adaptive learning technique, apply a sample image as an input and can reveals the likelihood of being a special colour for each pixel through the image. The intensity of each pixel shows this likelihood in the grey level output image. After choosing threshold value, a binary image is obtained, which can be applied as a mask to segment desired colour in input image. To show the efficiency of the proposed method, we use it to segment skin colour, and compare obtained results to some famous algorithms. With 96.8% true positive and 25% false positive, the accuracy of system is proved.

KEYWORDS: Fuzzy System, Colour Image, Segmentation.

1. INTRODUCTION

Segmentation is a process that partitions an image in to regions [1]. Image segmentation is an essential but critical component in low level vision, image analysis, pattern recognition, and now robotic system. Not until recently has colour image segmentation attracted more and more attention mainly due to reasons such as the ones below:

- Colour image provide far more information than grey-scale images and segmentations are more reliable.
- Computational power of available computers has rapidly increased in recent years, being able even for PCs to process colour images.
- Handing of huge image databases, which are manly formed by colour images, as the internet,
- Outbreak of digital cameras, 3G mobile phones, and video sets in everyday life.
- Improvement in sensing capabilities of intelligent systems and machines.

Common approaches for colour image segmentation are clustering algorithms such as K-means [2] or mixture of principal components [3]. However, these algorithms do not take spatial information in to account. Some progress has been made on this issue; steel, much experimentation still needs to be done [4].

One of the most useful applications of the colour image segmentation is object detection. Simple segmentation by colour thresholding may be insufficient in this case.

In this paper a novel method is described which can segment special colour in an input colour image. Using accurately designed fuzzy inference system (FIS) which is supposed to successfully overcome the complexity and uncertainty of image segmentation, acceptable results are obtained. To show efficiency of designed algorithm, it is applied to skin detection. Results improve the robustness of algorithm compare to other works.

A brief description of FIS is presented in section 2. In section 3 different steps of algorithm designing are discussed some experimental results are shown in section 4 and the paper is concluded in section 5.

2. Fuzzy Inference System

Fuzzy sets theory provides a framework to materialize the fuzzy rule-based (or inference) systems which have been applied to many disciplines such as control systems, decision-making and pattern recognition [5]. The fuzzy rule-based system consists of a fuzzification interface, a rule base, a database, a decision-making unit, and finally a defuzzification interface [6]. These five functional blocks are described as follow:

- A rule base containing a number of fuzzy IF-THEN rules.
- A database which defines the membership functions (MF) of the fuzzy sets.
- A fuzzification interface which transforms the input crisp values to input fuzzy values.
- A decision-making unit which performs the inference operation on the rules and producing the fuzzy results.
- A defuzzification interface which transform the fuzzy results of the decision-making unit to the crisp output value.

In order to perform the inference operation in the fuzzy rule based system, the crisp inputs are firstly converted to the fuzzy values by comparing the input crisp values with the database membership functions. Then IF-THEN fuzzy rules are applied on the input fuzzy values to make consequence of each rule, as the output fuzzy values. The outputs

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obtained for each rule are aggregated in to a single output fuzzy value, using a fuzzy aggregation operator. Finally, defuzzification is utilized to convert the output fuzzy value to the real world value as the output.

Sugeno type is one the commonly used fuzzy inference method which is employed in this study as well. The Sugeno fuzzy model was proposed by Takagi, Sugeno, and Kang in an effort to formalize a system approach to generating fuzzy rules from an input–output data set. Sugeno fuzzy model is also known as Sugeno–Takagi model. A typical fuzzy rule in a Sugeno fuzzy model has the format:

IF x is A and y is B THEN $z = f(x, y)$,

where*AB*are fuzzy sets in the antecedent; $Z=f(x,y)$ is a crisp function in the consequent. Usually $f(x,y)$ is a polynomial in the input variables x and y, but it can be any other functions that can appropriately describe the output of the output of the system within the fuzzy region specified by the antecedent of the rule. When $f(x,y)$ is a first-order polynomial, we have the *first-order* Sugeno fuzzy model. When f is a constant, we then have the *zero-order* Sugeno fuzzy model, which can be viewed either as a Special case of the Mamdani FIS.

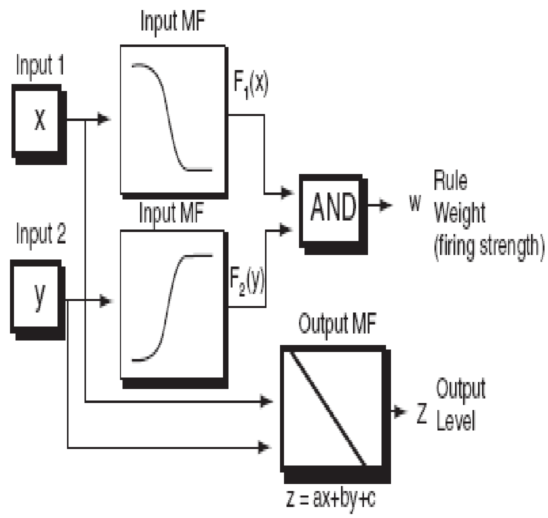


Fig.1. An example of Sugeno fuzzy system

Where each rule's consequent is specified by a fuzzy singleton, or a special case of Tsukamoto's fuzzy model where each rule's consequent is specified by a membership function of a step function centered at the constant. Moreover, a zero-order Sugeno fuzzy model is functionally equivalent to a radial basis function network under certain minor constraints. Figure 1 depicts an example of Sugeno fuzzy model.

3. Proposed Method

The proposed system is a Sugeno type fuzzy inference system. This system is used as a classifier to segment special colour in an input image. A training set of desired colour is needed to design and after that, the system could be applied in any arbitrary image to segment the special colour. More details are in following sections.

3.1 Colour Space Selection

What we commonly call colour is actually our perception of light waves from a thin band of frequencies within the electromagnetic spectrum. This region of visible light ranges from about 4.3×10^{14} hertz to about 7×10^{14} hertz. Individual colours are identified by their dominant wavelength λ (which represent hue), excitation purity (which represent saturation), and luminance (which represents intensity). We often refer to colour by their dominant wave length. Using this notation, colours range from about 400 nanometers for violet to about 700 nm for red. Computer scientists use colour models to describe different colours.

Many different colour models exist in computer graphics. Each model uses its own 3D coordinate system to identify uniquely individual colours. Some models (e.g. CIE XYZ, CIE LUV) are capable of representing all colours from the visible colour domain. Other models (e.g. RGB, HSV) are restricted to a subset of this domain. Certain models (e.g. CIE LUV, CIE Lab, Munsell) have been designed to try to provide other useful properties like isoluminance and control over perceived colour difference.

The transformation of RGB to perceptual colour space is invariant to high intensity at white light, ambient light and surface orientations relative to the light source; consequently they can be a suitable choice for colour segmentation methods.

By following non-linear equations, RGB colour space is transform to HIS colour space, which has the advantage that intensity component is separated from chrominance components:

$$H = \arccos \frac{\frac{1}{2}((R-G)+(R-B))}{\sqrt{((R-G)^2+(R-B)(G-B))}} \quad (1)$$

$$S = 1 - 3\frac{Min(R,G,B)}{R+G+B} \quad 1. \quad (2)$$

2. $$I = \frac{1}{3}(R+G+B) \quad 2.1. \ (3)$$

As the intensity varies according to environment conditions and simply discarding luminance information affects the model's accuracy, we prefer to reduce the effect of this component for more adaptable work. So we combine our colour space by three components include: $(H, S, \frac{1}{3}I)$.

3.2 Designing Fuzzy inference System

After transforming the input image in to the selected colour space, next step is searching the pixels with special colour, through the image. This colour can be any colour like red, green, blue, yellow, etc or the colour of particular object such as vegetables, fruits or even human body skin.

Sugeno fuzzy system used is a 1-input, 1-output system applying the Euclidean distance between the colour of each pixel to the average target colour sub-space as an input, and the likelihood of being target pixel as an output. 150,000 colour vector, contain the pixel of target colour and also any other colour, should be provided as a training data set. Our FIS is designed by neuro-adaptive learning techniques. These techniques provide a method for the fuzzy modelling produce to learn information about a data set, in order to compute the membership function parameters that best allow the associated fuzzy inference system to track the given input/output data. This learning method works similarly to that of neural networks.

Here, first subtractive clustering [7] is implemented on data. After deciding about number of MFs with this method a hybrid learning algorithm to identify parameters of Sugeno-type fuzzy inference system is used. It applies a combination of the least-square method and the backpropagation gradient descent method for training FIS membership function parameters to emulate a given training data set. The outputs are linear and *weighted average* method is used for defuzzification [6].

When the sample image is used as an input for designed FIS, an output image is a grey-level image. The intensity of each pixel, show the probability of being a target colour vector. We need a binary image to make mask and segment regions with designed colour in the input image. So, the value as the threshold should be selected. After investigating various results, 87% is chosen as the best threshold value. It means that the pixels with %87 likelihood or more are regarded as target pixels. The binary image is formed by setting target pixels to 1 and all other pixels to 0. After this, morphological processing, consist of filling holes and opening followed by closing [8], is accomplished to acquire separated and connected regions.

To show the efficiency of this method, we design system for skin colour detection. The input MF is shown in Figure 2 (A). To better understanding the semantic meanings, which are: *Not Skin, Low probability Skin, Rather Skin and Skin*, is assigned to four obtained clusters.

This system contains 20 nodes and 4 fuzzy rules. If we define: Z={ *Not Skin, Low probability Skin, Rather Skin, Skin* }, then the rules are:

IF input is *Z* THEN output is *Z*.

Figure 2 (B) shows an example of rules composition. In this example the output 0.9 is achieved for the input 0.2.

In next section obtained results are discussed.

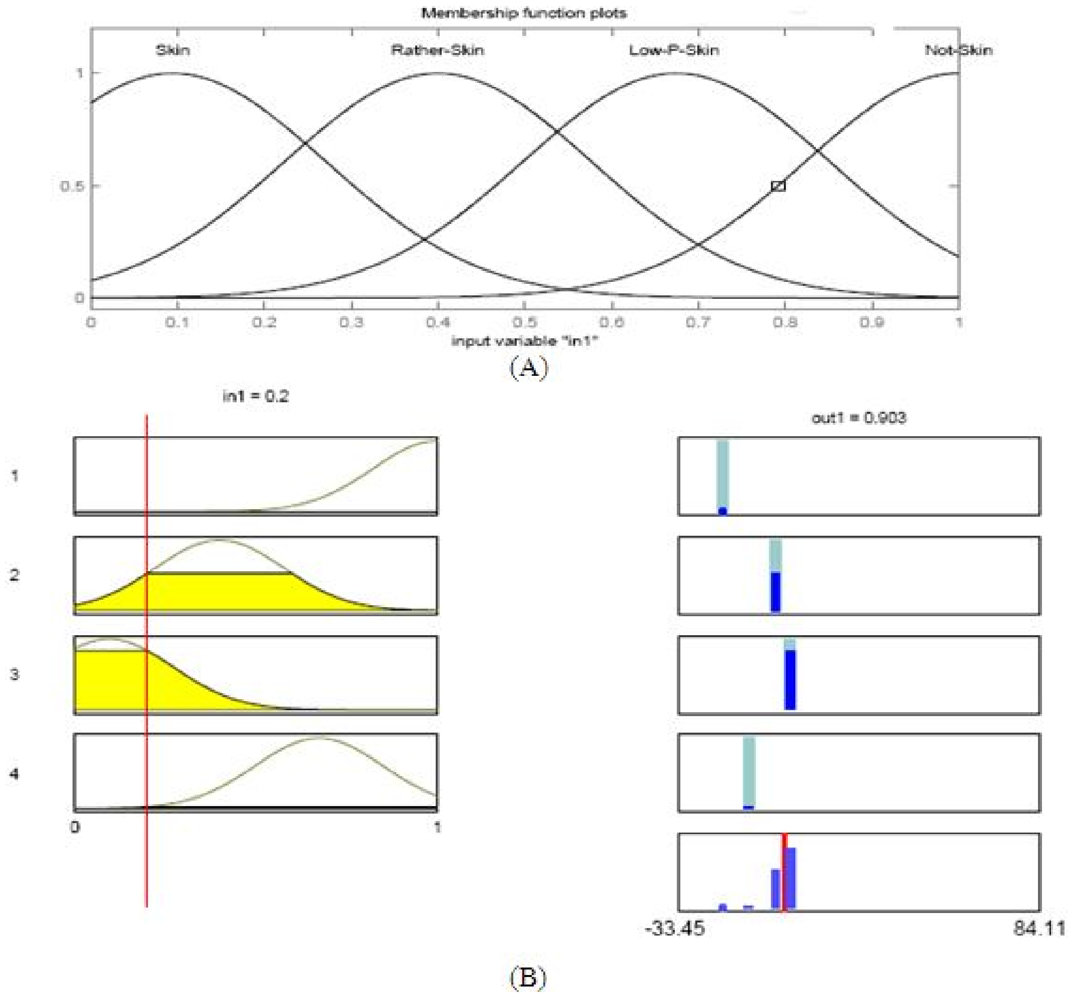
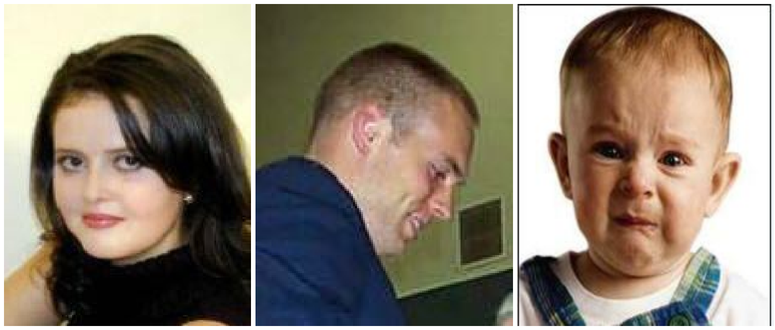


Fig.2. (A) Input Membership Function with Four Clusters, (B) An example of composition of rules

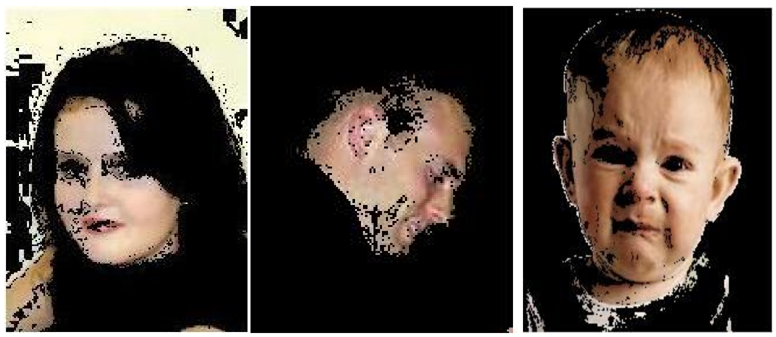
4.Experimental Results

To evaluate the performance of the proposed colour image segmentation, some experiments are carried out to detect human body skin colour detection. This system can be so useful for the understanding the image where human are subject of observation, for example gesture recognition, face detection, motion capture etc [9]. Some output results are observable in Figure 3. To obtain connected and separated regions in binary image some morphological processing, contain opening and closing [8], are performed.

To compare the system with other works, we apply it on Bao [10] image database. This database includes 370 face images from various races, mostly from Asia, with wide range of size, lighting and background. Although different methods use slightly different separation of the database in to training and testing image subsets and employ different learning strategies [11], we show our results beside some other robust works in Table 1. As it is observable, our method shows more accurate performance compare to other algorithms. So it is applicable as the reliable technique to segment any colour through the input colour image.



(a)



(b)

Fig.3. (a) input image, (b) detected skin pixels

Table 1. Experimental Results

Method	*TP (True positive)*	*FP (False Positive)*
The proposed method	96.8%	25%
Brand and Mason [12]	94.7%	30.2%
Lee and Yoo [13]	90%	30%
Brown et al. [14]	78%	32%

5. Conclusion and Future Works

In this paper a novel fuzzy method was suggested to colour image segmentation. Designed system was an optimized neuro-fuzzy one, which applies an image as input and could reveals the likelihood of belonging to special colour group, for each pixel, in a grey level image as an output. This technique was applied to segment skin colour detection and 96.8% true positive proves the efficiency of system compare to other works (Table 1).

Design a full automatic system to segment all the different colours in an image, is our next plan. For more application see [15-18]

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