Skin Recognition

Using Fuzzy Logic Approach

ABSTRACT

In this document we use fuzzy inference systems; Mamdani and Sugeno approach along with adaptive neuro-fuzzy inference method to recognize human skin based on the intensity value of the pixel samples. Along with fuzzy approach we have also studied results from pure Neural Network approach. We evaluate Madnani inference method and give comparative analysis of all systems.

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Neural Networks and Fuzzy Systems

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Introduction

In this modern era of technological advancement, humans are trying hard to automate things and make them artificially intelligent so that these things can adopt the creative capabilities like themselves. Science is trying to develop a brain like systems and giving more than just the five basic senses and sight is one of them. We are teaching computer how to understand pictures, so they could see what we humans can. In this story of computer vision, making ourselves visible to computers need much effort. And one part of it is detecting skin, not just one shade but all the shades evolution has crafted over the years. From tracking video to camera auto focusing to detecting humans, everything needs skin detection and that is what we are achieving in this document.

We use Fuzzy logics, Neural Network and their amalgam (anfis) to detect skin or non-skin pixels from an image. There are certain drawbacks which has solutions too. Firstly, skin colors are limited and have no exact boundaries between the shades. A problem can be arouse as in RGB color space the boundary between skin and nonskin pixel is not exact; but converting RGB to YCbCr as described in this journal referenced, can make things easier for fuzzy systems [1].

Background

Overview about the data

Our systems (fuzzy logic and neural network based) are trained and further tested on the data set available at UCI Machine Learning repository which has the dataset with values collected by randomly sampling B,G,R values from the images of faces of different age group(young, middle, and old), race groups (White, Black, and Asian), and genders.

The total data count is 245057; where 50859 the samples collected from skin images and 194198 are samples collected from nonskin part of the image. The data is stored in sorted order and have four columns where first three columns are BGR values respectively and last column has output showing one and two as skin and nonskin respectively.

Methodology developed in the literature

Researchers in literature describe different schemes to recognize which pixel is skin and which is not. One technique that recently became very famous is "*Human Skin Detection Using RGB, HSV and YCbCr Color Models*" It uses three color spaces RGB (Red, Green, Blue), HSV (Hue, Saturation, Value) and YCbCr (Luminance, Chrominance) color models. The Algorithm use not only one color space ranges but multiple that in result increases the accuracy[2]. Most common technique is applying fuzzy logics and developing a fuzzy inference system that classify the data into skin and nonskin classes. They develop user supplied human language rules and then the fuzzy system converts it into mathematical equivalent. This scheme is famous because of its flexibility as fuzzy logics can handle problems with imprecise and incomplete dataset.[1]

Another technique discussed in literature is developing an approach based on neural network which are also useful in mapping inputs to outputs.

Many paper praises about Fuzzy Logic toolbox as very useful in journals. As it provides the user with adoptive techniques like adaptive neuro-fuzzy inference system (ANFIS).[3]

Main Part

Methodology Developed

First technique I am following is described in this paper "*Skin Color Segmentation in Fuzzy YCBCR Color Space with the Mamdani Inference"* from *American Journal of Scientific Research* by M. Iraji, Saber and Yavari, Ali. [1]

Second approach is developing a neural network approach. Which only takes an input and output to devise a pattern matching system.

Another approach is changing the inference system to Sugeno. And using adaptive neuro fuzzy inference system that make rules and train itself on the given data.

Before diving deep into the methodologies that we have developed, let's get a fare understanding of what these methods are.

Mamdani Inference Method

This technique is based on Mamdani inference methodology, which is mostly used and oldest inference technique fabricated by Ebrahim Mamdani in 1975 using fuzzy set theory(out of scope for this report)[4]. It was formulated to control steam engine and boilers based on the if else rule obtained by the factory workers.

It takes input and map them to values between zero and one based on the membership function used to inference. These values are then dispensed to the predefined rules that in result give us outputs which then supplied to defuzzification function that makes fuzzified values to a crisp output.

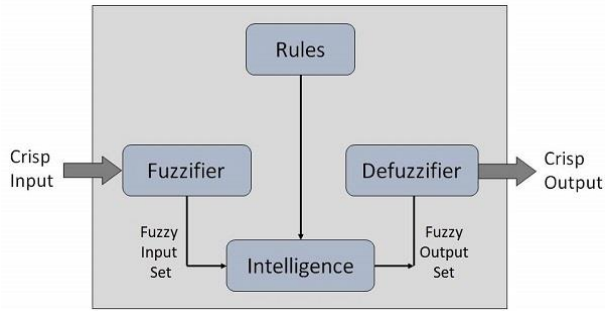


Figure 1 [5]

Sugeno Inference Method

Another related fuzzy inference model used here other than Mamdani is Sugeno proposed by Takagi, Sugeno, and Kang in 1985 which since then is the holy grail for generating fuzzy rules on the bases input-output data. [6]

The only difference between fuzzy and Sugeno is of the output function that in Sugeno case is constant or linear. Sugeno methodology is mostly used with the technique known as Anfis (Adaptive Neuro-fuzzy Inference System) which uses neural network to devise a model that fabricate rules on the bases of the input data and output expected.[6]

Neural Network Based Approach

Neural Network is technique of devising pattern with the help of some organized data. Neural networks are considered quite good at this. Considering the inner architecture, we can find two types of NN's.

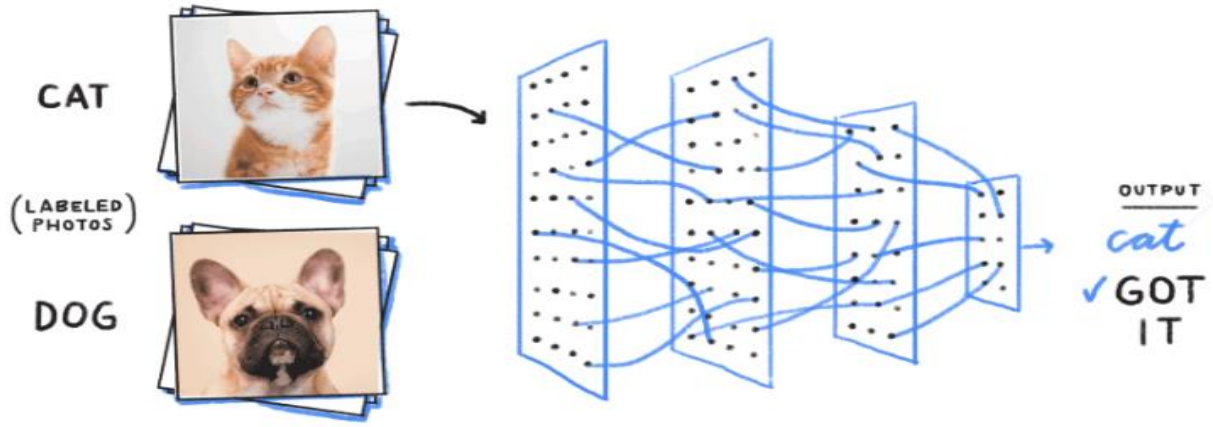
- Recurrent Neural Network: Where the neurons in the layers are joined in a circular manner.
- Feedforward Neural Network: Where the layers are connected in a liner way.

We can think of it as a composition function where we give different inputs and it gives you some output. Artificial Neural Network consider the architecture of human brain where neurons get input from the previous neuron and after definite process they categorically snap an output that is the input of other neurons and so on until the output layer. Under the hood, the structure of neural network is based on the following parts.

- Neurons
- Weights
- Biases
- Activation Function
- Layers

These units are what we need to construct a basic neural network. With the manipulation of these we can increase or decrease the accuracy and complexity of our problem.

As the problem is simple enough to map to a neural-network based approach, so we have also used this same approach just to compare to the results of the pure fuzzy logic-based approach and adaptive neuro-fuzzy approach (Anfis). The detail of this approach is out of the scope of this report.



Design decision

Iterative process is what design decisions are in software design. It includes requirements, architecture, implementation, and testing.

Requirement Specification

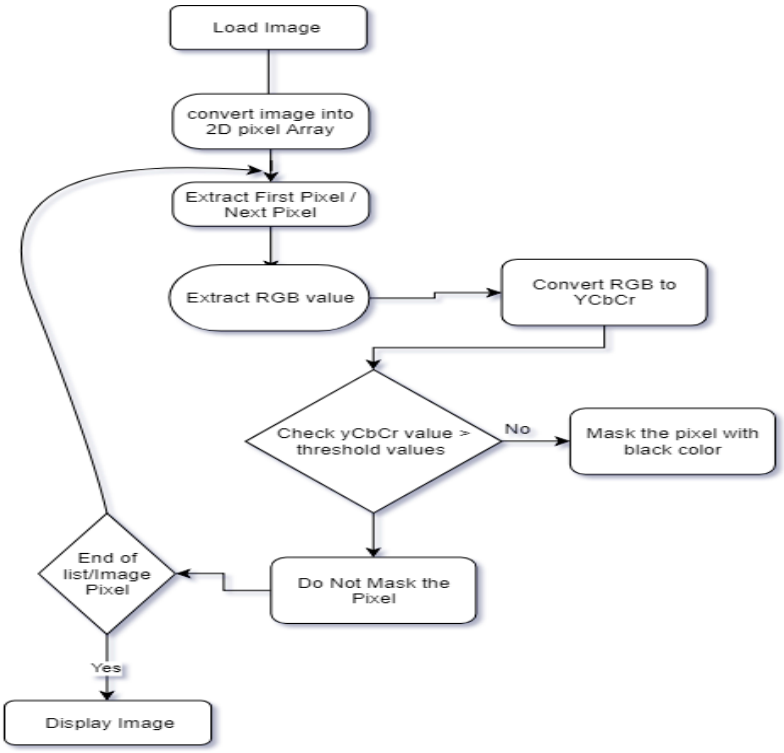
It has been decided from the beginning that the purpose of this software would be of differentiating of human skin pixels from nonskin pixels. For this purpose, MATLAB is being used with its fuzzy logic tool box.

System Architecture

After specifying the requirements, system architecture is where we define how are we going to do it.

Mamdani

Our system adopts two fuzzy inference methodologies to solve this problem; One is Mamdani and the other is Sugeno. Following design decisions were developed both for Sugeno and Mamdani approach made based on the algorithm selected as describe in the Methodology Developed.

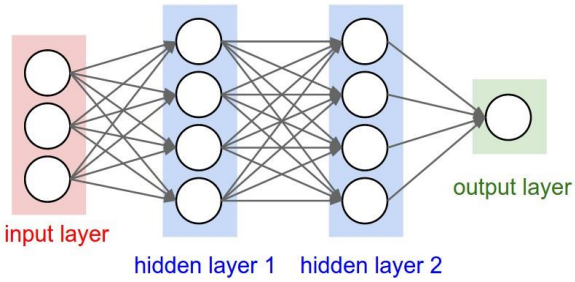


Anfis with Sugeno

The Sugeno approach will be used with ANFIS method as it will be creating rules, inference methods membership function and the output is then mapped to linear or constant output function.

Neural Network

In Neural Network approach we develop a NN with hidden layers and add input values along with output expected. This will make the neural network train and after it would be tested for accuracy detection. The training and error correcting algorithms would be gradient decent with back propagation.



Implementation Techniques

Preprocessing

Data was simple and easy to use to implement the system. Following steps have been taken to make the data machine readable and accordance with the methodology which we follow. All the steps have been taken after importing the dataset in MATLAB.

For Mamdani

BGR To RGB Conversion: At this step we have used MATLAB function fliplr to swap the R column with B. It is because the formula for conversion we are using is based on RGB order of color space.

RGB To YCbCr: This step is the main step in following the methodology. Following formula has been coded in matlab to convert rgb values.

$$\begin{bmatrix} Y \\ C_B \\ C_R \end{bmatrix} = \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} + \frac{1}{256} \begin{bmatrix} 65.738 & 129.057 & 25.064 \\ -37.945 & -74.494 & 112.439 \\ 112.439 & -94.154 & -18.285 \end{bmatrix} \bullet \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

For Adaptive-Neuro Fuzzy inference system.

Separating training and testing data: Unlike Mamdani it uses neural network to devise rules, so it needs a training data and a testing data. We separate skin and nonskin data and then we combine them according to the percentage given for the training and testing data.

For Neural Network

Separating training and testing data-based percentage decided.

Model Solution Implementation

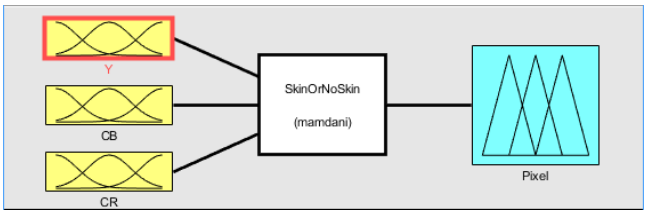
Mamdani Inference System

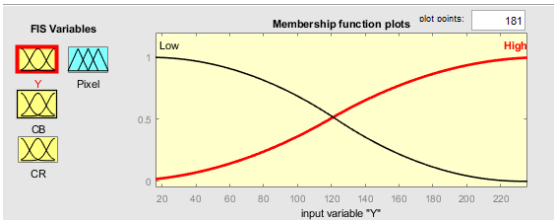
Making of fuzzy System

Inputs

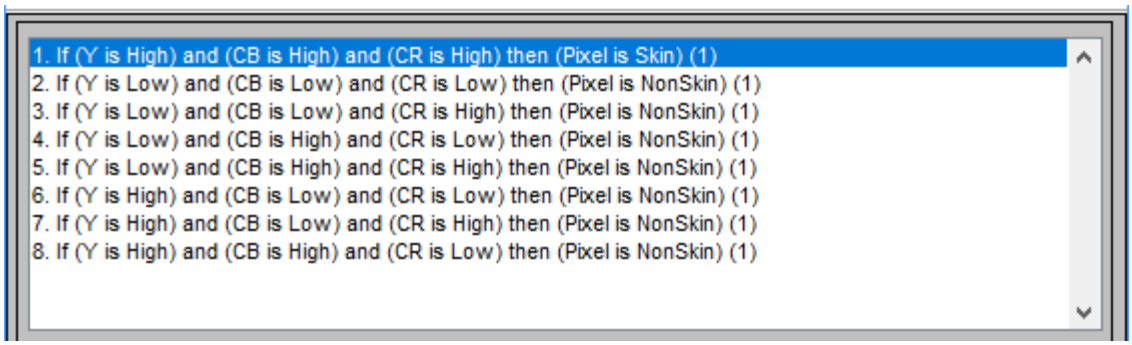
In input we use three variables to get crisp values which is then scaled in the range between 0 and 1 using subjective membership function of that variable. Each variable has its own membership function that decides the value on to which the input is mapped. Membership functions are just a curve that map each point to a value between 0 and 1.

Black Box aka the inference system

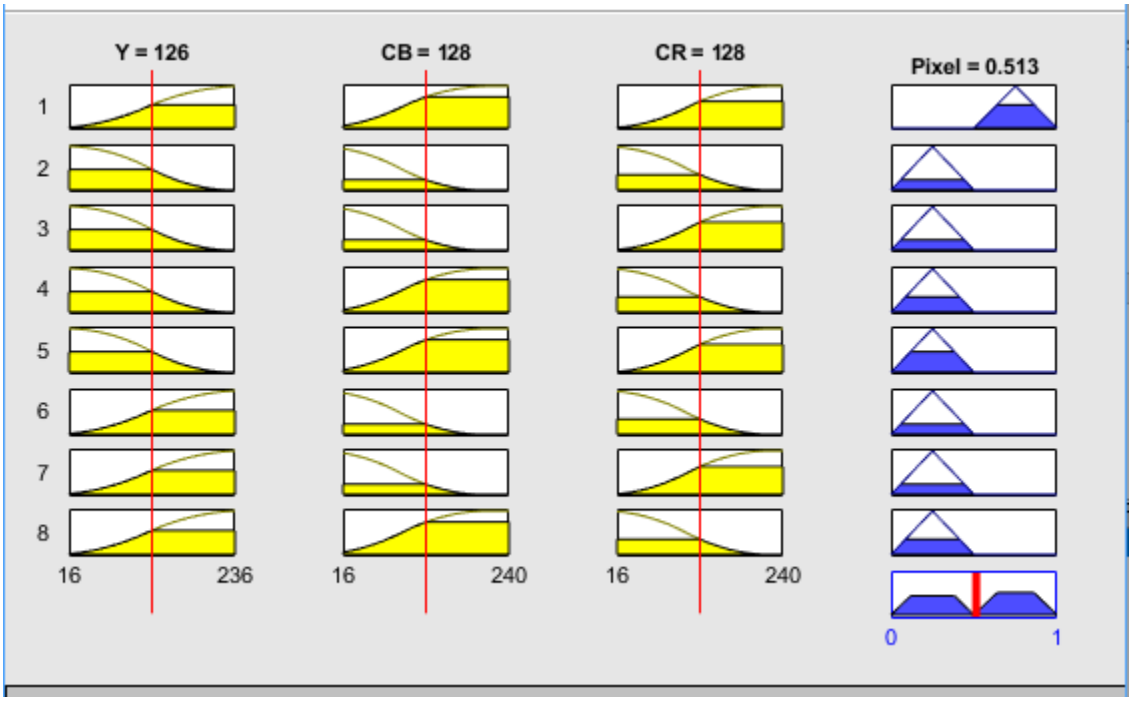




At this step system dispense the scaled inputs to the predefined rules. The pre-fed rules are human classified and are as follow [1].



The system infers these rules and develop a fuzzified outputs. With help of defuzzification function, in our case it is centroid, the outputs are defuzzified into a crisp result.



MATLAB Implementation

A pre-defined fuzzy inference object which is having all the input and output details along with the rules is fed to the system using readfis method which then further supplied to evalfis method that take Input data and fis object to evaluate this fuzzy inference system. The evalfis method return a single column of results having all the guessed defuzzified outputs which we will use to check the accuracy after manually transforming it like the original outputs.

Accuracy

We will convert the defuzzified output (which is in between 0 and 1) into a value that is more like the original output value, by intelligently setting the threshold in this case we are setting it to 0.53. The values which is greater than the threshold are replaced with 1 (the identity of skin in the original output) and the values which are less than the threshold are replaced with 2 (the identity of nonskin in the original output). The accuracy is found by comparing the new output with the old one.

Adaptive Neuro-Fuzzy Inference system

In this section we fed the whole data set to the anfis method of MATLAB as this use Sugeno which is Multiple Input Single Output (MISO) system so it automatically separates the last output column and build the rules based on the first three input columns and gives us the FIS object based upon it. The evaluation is done in the same with evalfis method of MATLAB.

Accuracy

Here in this approach, to find the accuracy we use round method of MATLAB to round the values, as output will be greater than 0.5 and less than 2.5. Every value which is in range of 0.5 to 1.5 will be converted to 1 1 (the identity of skin in the original output) and values greater than that will be converted to 21 (the identity of nonskin in the original output) and then the accuracy is found by comparing the new output with the old one.

Neural Network Approach

In this approach we separate the training and testing data first in the code. After that we uses MATLAB's `feedforwardnet`function to build a neural net. After building neural network and setting its custom weights we use MATLAB's train function along with the net object to train it over the training data set. After getting the trained neural network we test it by using sim method using testing data set. And at the end we have calculate the accuracy. Details of this approach is hidden as it was not the demand of this report. It is explained because we have done comparative analysis on the accuracy.

Results

Methodology	Mamdani	Anfis	Neural Network
Train Data Percentage*	N/A	80	80
Test Data Percentage*	100	20	20
Accuracy	82.9554	96.7925	96.0574

*Training and testing data is formulated based on the equal distribution of the skin and nonskin percentages.

Experimental Results and Analysis

Mamdani Inference System Evaluation Result

System Details

The Mamdani inference system does not need any training data to work with it is just require data to test the approach programmed in the Fuzzy Inference System (fis) object passed to it.

Membership Function

It is a curve that instructs how each input maps to a membership value between 0 and 1.

Input

SMF and ZMF are both input function used f-or input scaling.

Output

As we have to classify output into two classes of skin and nonskin that is why Trimf in the function used here for output scaling.

Defuzzification Method

Centroid is the defuzzification method used here.

Hypothesis

“Accuracy of the system depends on the defuzzification function.”

Experimentation*

Defuzzification Function	Accuracy
Centroid	82.9554
Bisector	83.4430
MOM	78.8992
LOM	78.8384
SOM	78.8992

*for this experimentation the data other variables were same for every test conducted.

Conclusion

Accuracy is changing as the defuzzification function changes. Defuzzification is the process of quantifying the fuzzy set into a crisp result. Changing the defuzzification function means what to choose from the fuzzy set; let us say from the fuzzy set you want upper bound value, lower bound or middle value etc.

Here bisector and centroid are those function which giving the most accuracy as compare to the other defuzzification function. As Centroid takes the center of the area under the graph that was formed in the accumulated results drived from the fuzzy set whereas bisector bisect that graph.

Comparative Analysis

Comparative Analysis of Mamdani Fuzzy Inference System, Adaptive Neuro Inference System and Neural Networks is performed to quantify the efficiency of these systems and how and in what manner are they differ from each other.

Result Gathered

Following table will test the systems on different amount of training and testing data.

Methodology	Mamdani	Anfis	Neural Network
Training data Percentage	100	60	60
Accuracy	82.9554	92.1589	94.6222
Training data Percentage	100	80	80
Accuracy	82.9554	96.7925	96.0574
Training data Percentage	100	60	60
Accuracy	82.9554	92.1589	94.6222

Comparison

Mamdani	Neural Network	Anfis
Does not depend upon the training data.	Depends upon the training data.	Depends upon the training data.
Changing in training data won't affect the accuracy as it is independent on the dataset.	As the amount of training data increases the neural network learn more details and so they give best result.	Changing in training data changes the accuracy as it is Neural Network dependent which require adequate amount of training data and epochs to learn.
It works on the predefined rules that's why it has constant accuracy.	Its accuracy is fluctuating because its data proportional	Same is the case with this inference method as it is also data dependent.
Rules are predefined	No rules, just bunch of layers and hidden layers do the math.	Rules are defined in effect to the training data supplied.
Mainly the accuracy is dependent on the defuzzification function. Which is in this case is centroid.	No defuzzification function involved; Output layer do the work	Also in this inference method the accuracy is mostly dependent on the defuzzification function

		Which is in this case is waited average.

Conclusion

Anfis and Neural Network give high accuracy because they both data dependent and tweak themselves in accordance with the data provided. Whereas Mamdani fuzzy inference system is dependent upon the membership function and defuzzification method as seen in the above hypothesis.

[1] C. Reads and C. S. E. E. Profile, “Skin Color Segmentation in Fuzzy YCBCR Color Space with the Mamdani Inference Skin Color Segmentation in Fuzzy YCBCR Color Space with the Mamdani Inference,” no. May, pp. 131–137, 2015.

[2] S. Kolkur, D. Kalbande, P. Shimpi, C. Bapat, and J. Jatakia, “Human Skin Detection Using RGB, HSV and YCbCr Color Models,” *Proc. Int. Conf. Commun. Signal Process. 2016 (ICCASP 2016)*, vol. 137, pp. 324–332, 2017.

[3] M. F. Azeem, *Fuzzy Inference System - Theory and Applications*. InTech, 2012.

[4] E. H. Mamdani and S. Assilian, “An experiment in linguistic synthesis with a fuzzy logic controller,” *Int. J. Man. Mach. Stud.*, vol. 7, no. 1, pp. 1–13, Jan. 1975.

[5] “fuzzylogic_system.jpg (600×311).” [Online]. Available: https://www.tutorialspoint.com/artificial_intelligence/images/fuzzylogic_system.jpg. [Accessed: 30-Dec-2018].

[6] T. Takagi and M. Sugeno, “Fuzzy identification of systems and its applications to modeling and control,” *IEEE Trans. Syst. Man. Cybern.*, vol. SMC-15, no. 1, pp. 116–132, Jan. 1985.