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Human Emotion Detection using Image Fusion Technique

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Abstract: *Human emotion detection is a very essential and complex process. Any psychological problem can be detected at its initial stage if emotions can classify distinctly. In this paper six emotions (happy, sad, surprise, angry, fear, neutral) are classified using Back Propagation Neural Network based on six features before and after fusion of images. The comparisons between the pure emotions with fused emotions are done. Image fusion is done by min-max technique. It is seen that fused image gave better efficiency than pure image. KDFF database is used for emotion analysis. Sensitivity & Specificity of the fused emotional image are increased by 16.72% and 27.75% respectively.*

Keywords: *Back Propagation Neural Network, Feature Extraction, Human Emotions, KDFF database, Image Fusion*

I. Introduction

Human emotion [5][6] detection is a challenging task. Human beings react differently in same situation also. There are different types of emotion recognition systems exist, such as facial expression based emotion detection [4], EEG signal based emotion detection, fMRI based emotion detection, and speech signal based emotion recognition and so on. In this paper image fusion technique is used for emotion detection with higher efficiency. Primarily, six pure emotions like Happy, Fear, Angry, Sad, Surprise and Neutral facial expressions are taken from KDFF database and six features are extracted. The features are Mean, Standard deviation, Skewness, Entropy, Nyquist, Second derivative sum of fast fourier transform. All the six features are also extracted from fused human emotional images also. The image fusion is done by min-max algorithm. The two images are first merged by Wavelet decomposition of level five and then maximum is taken for approximation and minimum is for the details. The mathematical expressions for different features are

1. **Mean**$(\boldsymbol{X}) = \frac{\sum \boldsymbol{X}}{\boldsymbol{N}}$ (1)

Where X=Mean, ∑X= summation of image pixels and N= Number of pixels

2. **Standard Deviation (μ)**= $\sqrt{\mathbf{1}/\boldsymbol{N}\sum_{\boldsymbol{i=1}}^{\boldsymbol{N}}(\boldsymbol{xi}-\boldsymbol{x})(\boldsymbol{xi}-\boldsymbol{x})}$ (2)

Where μ=Standard Deviation, N=total number of pixels, xi= each value of pixel, x= arithmetic mean of pixels

3. **Median (Mdn)=1** $+\left(\frac{\frac{N}{2}-\sum f0}{fw}\right) * \boldsymbol{i}$ (3)

Where Mdn= Median, N=Total number of pixels, ∑f0= summation of frequencies of pixels, fw= frequency of pixels within the interval containing the median

4. **Skewness = 3(Mean-Median)/Standard Deviation** (4)

5. **Entropy(H)= -**$\sum_i \boldsymbol{PiLog2\ Pi}$ (5)

Where H= Entropy, Pi= Probability of instantaneous pixels

6. **Fast Fourier Transform (FFT)**$\boldsymbol{X}(\boldsymbol{k}) = \sum_{\mathbf{0}}^{\boldsymbol{N-1}} \boldsymbol{x}(\boldsymbol{n})\boldsymbol{e}^{-\boldsymbol{j2\pi nk}}$ (6)

Nyquist= Sampling of FFT (7)

7. **Second Derivative sum of FFT=**$\sum \frac{d2}{dt2}(X(K))$ (8)

The above features are calculated for both general human emotional images and fused emotional images. Both the features are classified by Back Propagation Network of Artificial Neural Network. Both the results are compared and found that sensitivity and specificity as well as accuracy are improved for fused image.

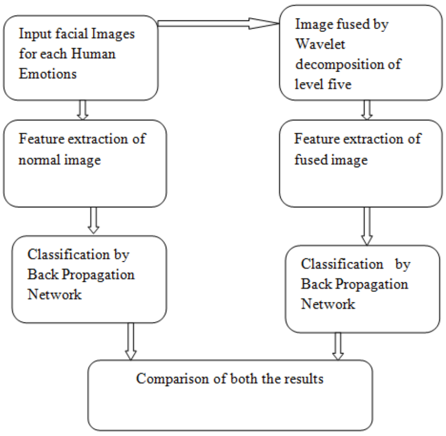

Fig. 1 Flow Diagram

The flow of the work is explained in Figure 1. The sensitivity and specificity can be calculated from the tested result. In this paper, fifty subjects are tested for six emotions before and after fusion and classified. 35 subjects are used for training and 15 subjects are used for testing. Sensitivity & Specificity can be calculated as
Sensitivity= true positives/(true positive + false negative) & Specificity=true negatives/(true negative + false positives)

II. Image Fusion Technique

Wavelet analysis [1][2] is similar to Fourier analysis in the sense that it breaks a signal down into its constituent parts for analysis. Whereas the Fourier transform breaks the signal into a series of sine waves of different frequencies, the wavelet transform breaks the signal into its "wavelets", scaled and shifted versions of the "mother wavelet". In comparison to the sine wave which is smooth and of infinite length, the wavelet is irregular in shape and compactly supported. It is these properties of being irregular in shape and compactly supported that make wavelets an ideal tool for analyzing signals of a non-stationary nature [7]. Their irregular shape lends them to analyzing signals with discontinuity's or sharp changes, while their compactly supported nature enables temporal localization of signals features. This process of translation and dilation of the mother wavelet [8] is depicted below in Figure 2.

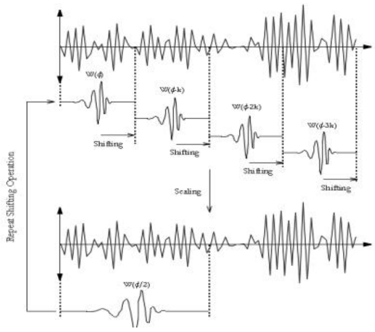

Fig. 2 Scaling and Shifting process of Discrete Wavelet Transform

After wavelet decomposition the fusion is done by Minmax estimation. It is possible that we have some prior information for an image, but it is rare to know the probability distribution of complex images. In this case, we have to find a “good” estimator whose maximal risk is. But this set doesΘminimal among all estimators. The prior information forms an image set. The risk of estimation F=DX is

r (D,f)=E$\{\|\boldsymbol{Dx}-\boldsymbol{f}||\boldsymbol{2}\}$ (9)

Since the probability distribution of image is unknown and the probability distribution of image in set precise risk cannot be calculated. Only a possible range is calculated. The maximum risk of this range is

r(D,S)=sup **E**$\{\|\boldsymbol{Dx}-\boldsymbol{f}||\boldsymbol{2}\}$ where f €S (10)

In Minmax estimation, the Minmax risk is the lower bound of risk in (10) with all possible, no matter linear or nonlinear, operators D:

$\mathbf{r_n}$ **(D,S)= inf r(D,S)** where D € O_n
(11)

III. Back Propagation Network

Back Propagation is a common method for training a neural network [3]. The basic structure of Back Propagation Network is given in Figure 3.

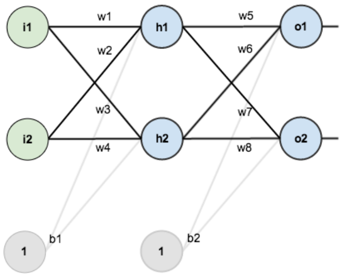

Fig. 3 Back Propagation Network

Here's how the total net input for h_1 is calculated:

$\mathbf{net_{h1}=w_1*i_1+w_2*i_2+b*1}$

(12)

Then it is squashed using the logistic function to get the output of h1

$\mathbf{out_{h1} = 1/1+e^{-\,net}{}_{h1}}$

(13)

Here's how the total net input for h_2 is calculated:

$\mathbf{net_{h2}=w_1*i_1+w_2*i_2+b*1}$

(14)

Then it is squashed using the logistic function to get the output of h2

$\mathbf{out_{h2} = 1/1+e^{-\,neth2}}$

(15)

Here's the output for o_1

$\mathbf{net_{01}= w_5* out_{h1}+ w_6* out_{h2} + b_2*1}$

(16)

$\mathbf{out_{01} = 1/1+e^{-\,net}{}_{01}}$

(17)

$\mathbf{net_{02}= w_5* out_{h1}+ w_6* out_{h2} + b_2*1}$

(18)

$\mathbf{out_{02} = 1/1+e^{-\,net}{}_{02}}$

(19)

$\mathbf{E_{01}= ½(Target^{01}-Out^{01})^2}$

(20)

$\mathbf{E_{02}= ½(Target^{02}-Out^{02})^2}$

(21)

$\mathbf{E_{total}= E_{01}+ E_{02}}$

(22)

By applying Chain rule,

$$\frac{\partial Etotal}{\partial w5} = \frac{\partial Etotal}{\partial out01} * \frac{\partial out01}{\partial net01} * \frac{\partial net01}{\partial w5}$$

(23)

The classification of the features is done by above calculations. Since six features and six emotions are taken, so six input layer neuron and six output layer neurons are used with six hidden layer neurons.

IV. Results & Discussions

In this paper the comparison between normal emotional image and fused emotional image is done. The facial images are taken from KDFF database. The images for six basic emotions from a single subject are show in figure 4.

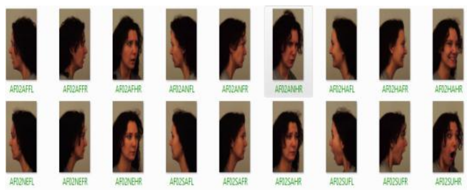

Fig. 4 Six basic emotions for three samples from single subject from KDFF Database

In the following figures six different emotions are shown after fusing of three samples from the same subject.

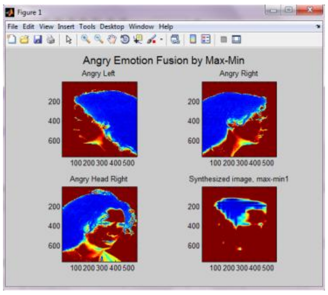

Fig. 5 Angry emotion fused by Wavelet Transform MaxMin decomposition

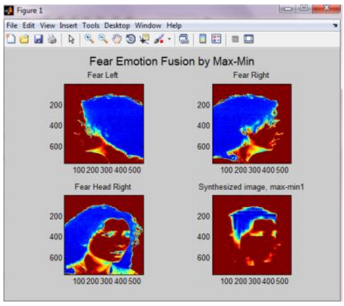

Fig. 6 Fear emotion fused by Wavelet Transform MaxMin decomposition

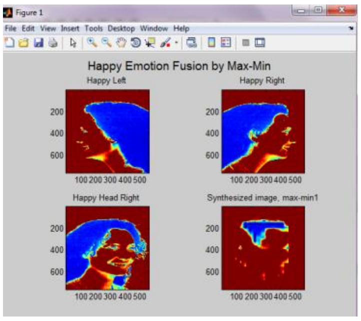

Fig. 7 Happy emotion fused by Wavelet Transform MaxMin decomposition

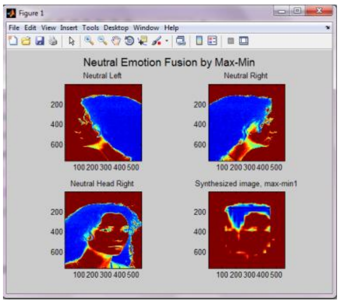

Fig. 8 neutral emotion fused by Wavelet Transform MaxMin decomposition

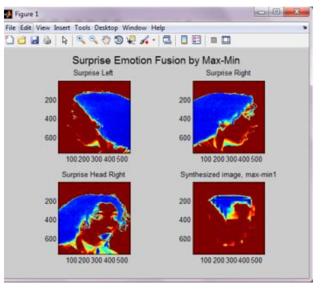

Fig. 9 Surprise emotion fused by Wavelet Transform MaxMin decomposition

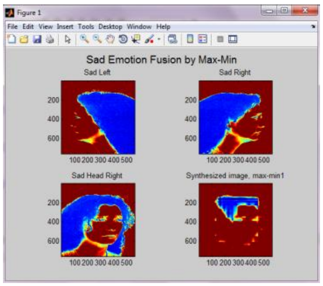

Fig. 10 Sad emotion fused by Wavelet Transform MaxMin decomposition

The features that are taken from fused and normal image are Mean, Standard deviation, Skewness, Entropy, Nyquist, Second derivative sum of Fast Fourier Transform. Classification is done by Back Propagation Network. The iteration versus error plot is shown better result for fused image classification.

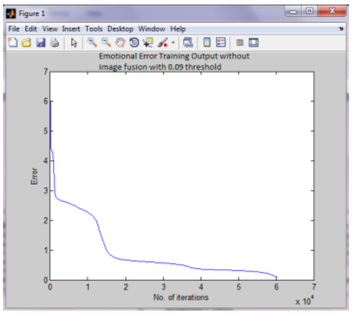

Fig. 11 Classification Error rate versus Iteration curve for emotional image without fusion for 251762 Iterations

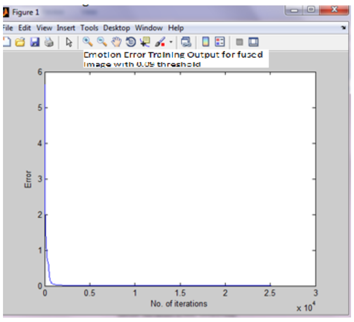

Fig. 12 Classification Error rate versus Iteration curve for emotional image with fusion for 60456 Iterations

The following Table 1 and Table 2 are giving the testing report of different emotions before and after fusion.

Table 1 Testing database before Image Fusion

S. No.	Fear	Angry	Happy	Neutral	Sad	Surprise
1	0.3999	0.5016	0.9864	0.6906	0.3195	0.9700
2	0.0399	1.0000	0.0000	0.9998	0.9365	0.0000
3	0.9999	0.9651	0.0000	0.0082	1.0000	0.0185
4	0.2439	0.5219	0.9951	0.7876	0.4043	0.0001
5	0.0397	1.000	0.0000	0.9998	0.9365	0.0000
6	1.0000	0.9713	0.0000	0.0102	1.0000	1.0000

Table 2 Testing database after Image Fusion

S. No.	Fear	Angry	Happy	Neutral	Sad	Surprise
1	0.0046	0.0211	1.0000	0.9998	0.9993	0.9682
2	0.0135	0.9998	0.0048	0.9713	0.9984	0.0154
3	0.9956	1.0000	0.0118	0.0497	0.9963	0.0000
4	0.0000	0.0211	1.0000	0.9796	0.9956	0.0064
5	0.0139	0.9998	0.0049	0.9720	0.9984	0.0158
6	1.0000	1.0000	0.0294	0.2907	0.9433	0.9101

Table 3 Classification result without image fusion

S. No.	Types of Emotions	True Positive (TP)	True Negative (TN)	False Positive (FP)	False Negative (FN)
1	Fear	17	10	11	12
2	Angry	20	10	11	9
3	Happy	22	13	6	9
4	Neutral	19	15	13	3
5	Sad	21	12	13	4
6	Surprise	16	17	9	8

Table 4 Classification result with image fusion

S. No.	Types of Emotions	True Positive (TP)	True Negative (TN)	False Positive (FP)	False Negative (FN)
1	Fear	22	19	5	4
2	Angry	25	17	3	5
3	Happy	28	18	2	2
4	Neutral	23	21	3	3
5	Sad	25	20	3	2
6	Surprise	21	16	8	5

Table 5 Specificity & Sensitivity without Image Fusion

S. No	Types of Emotions	Sensitivity	Average Sensitivity	Specificity	Average Specificity
1	Fear	58.62	72.6	47.62	54.80
2	Angry	68.97		47.62	
3	Happy	70.97		68.42	
4	Neutral	86.36		53.57	
5	Sad	84.00		48.00	
6	Surprise	66.67		65.38	

Table 6 Specificity & Sensitivity with Image Fusion

S. No.	Types of Emotions	Sensitivity	Average Sensitivity	Specificity	Average Specificity
1	Fear	84.62	87.18	79.17	82.55
2	Angry	83.33		85.00	
3	Happy	93.33		90.00	
4	Neutral	88.46		87.50	
5	Sad	92.59		86.96	
6	Surprise	80.77		66.67	

V. Conclusion

In this paper six emotions (happy, sad, surprise, angry, fear, neutral) are classified using Back Propagation Neural Network based on six features before and after fusion of images. The comparisons between the pure emotions with fused emotions are done. Image fusion is done by min-max technique. It is seen that fused image gave better efficiency than pure image. KDFF database is used for emotion analysis. Sensitivity & Specificity of the fused emotional image are increased by 16.72% and 27.75% respectively.

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