Pig Breeds Classification using Neuro-Statistic Model

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Abstract—Image classification using fully connected neural network is not efficient due to huge number of parameters in each layer. In this paper, we propose a Neuro-Statistic model for classification of five different pig breeds from pig images. The model consists of four sub modules which work together as a layered structure. We captured multiple individual pig images of five different pig breeds from different organized farms to conduct this research, segmented the captured pig images using hue based segmentation algorithm and then calculated the statistical properties like entropy, standard deviation, variance, mean, median, mode and color properties like H.S.V from the content of the individual segmented images. We fed all the extracted properties into Neural Network for Pig Breed (NNPB) to perform pig breed prediction with the classification module and analyzed the best performance, regression error plot, Error histogram and training state of NNPB. The performance of NNPB network was accepted based on error analysis and finally, we used the trained model to predict the breed of 50 pig images and achieved the prediction accuracy of 90%.

Keywords: *Classification, Regression, Histogram, Segmentation, Entropy*

INTRODUCTION

The animal breeds' classification is still a challenging task and there is no unique method that provides a robust and efficient solution to all situations (Islam, M.P., & Morimoto, T., 2017). The aim of classification is to assign a query object to one of class from a set of predefined classes based on the attribute values of the object. Artificial neural network (ANN) is widely used for classification of categorical data sets. The ANN uses many neurons which are computational units, connected with weighted links, inputs and biases. The neurons are producing output through activation functions and are transmitting it to the neurons at the next layer. The pattern which is to be classified is being fed into the network as input. The pattern will be processed through the network and produce some output. The error which will be calculated between predefined output and produced output. The training is to be performed to reduce error by adjusting weights of links associated layers and pattern classification neural network will be developed. The developed model will be validated by the predefined input patters and their assigned classes for tuning the hyperparameters. Finally, the model will be applied on test dataset for finalization. But, image classification using artificial neural network is computationally poor compared to data oriented classifications. The image is stored in computer as 2D matrix of pixels and each pixel is fed into input layer for image classification. The number of inputs is equal to the product of rows and column of 2D matrix. The same numbers of weights are also associated for input connections from input to a single neuron in the hidden layer. Generally, the fully connected neural network is used for classification. All hidden layers have same number of neurons and the number of neurons in the problem space is dependent on number of input parameters. The number of weights in fully connected layer with 1000 neurons for image is something like 150M for one layer. That is why the image classification using fully connected neural network is not efficient. Most of the researcher used convolutional neural network (CNN) for image classifications. The researchers

https://doi.org/10.22232/stj.2019.07.02.10

have used pre-trained model for classifying their images in transfer learning fashion where the features extraction part remains unchanged. They do not modify the feature extractions part and features of existing models to classify their own images. This problem motivated us to find new ways to classify the images based on the features extracted from its content. The aim of this paper is to develop pig breeds classification system based on statistical properties of the content of breed images and their color components. The five pig breeds named Yorkshire, Ghungroo, Hampshire, Mali and Duroc were captured from three organized pig farms. An arrangement was created at the time of capturing pigs to make the uniform background for all the pig images. The pigs kept moving freely and their site profile were captured by mobile phones with 10MP cameras. The 50 pigs were captured from each pig breed. We have segmented the pig images using hue based segmentation algorithms by us. The captured images are stored in computer memory as 2D matrix of pixels. We have extracted the statistical properties of the content of images like mean, median, mode, standard deviation, variance and color components like H, S and V values, from each segmented breed images. All computed statistical properties are fed into neural network and trained using supervised learning for mapping statistical properties with breed classes. We have developed a neural network for pig breed classification named NNPB which takes statistical parameters and color components as inputs and produces a single numeric value as output which is then categorized into pig breeds using the classification module. Out of 50 images for each breed, we have used 30 images for training the network, 10 for validating it and finally, 10 images for testing the network. We have used Matlab 2016 for extracting the values of the statistical parameters, color components and neural network. Finally, we used the trained model to predict the breed of 50 pig images and achieved the prediction accuracy of 90%. This type of work has not been done before in pig breeds classification. This is the reason for making this paper. The rest of the paper is organized into 7 sections excluding Section 1 which is Introduction. Section 2 is about the related works relevant to this paper. Section 3 describes the theoretical background needed for this paper. Section 4 & 5 explains the methods, tools and dataset used in this paper. Section 6 showcases the details of the results obtained and its implication. Section 7 consists of the concluding remarks and lastly the acknowledgements are given in Section 8 followed by the references.

RELATED WORK

Extraction and analysis of statistical features from images have been studied for a long time. Measuring statistical properties of pixel pairs at several distances in the image has been used for texture analysis (Wu & Chen, 1992). Image classification based on first and second order statistics calculated from digital images (Kahou & Sulema, 2010) and using such features to train neural image classifiers (Garg, Malhotra, & Singh, 2018) have been attempted. It is very important to measure the effect of such statistical measures on digital image processing (Kumar & Gupta, 2012) because it can be used to classify normal and abnormal mammograms (Youssef, Rabeh, Zbitou, & Belaguid, 2014). Specific applications of using statistical parameters as features include content based image retrieval (Thilagam & Arunesh, 2019) characterize images based on brightness distribution (Al-Ani & Alheeti, 2017) which describes the lighting condition in any image.

Various statistical parameters have been used to differentiate between human finger knuckles and acts as a high precision biometrics for individual human identification (Akheela & Naz, 2015).

Surface texture analysis using statistical-texture-features like surface morphology has been used to differentiate between defective and non-defective drug tablets based on external factors like temperature, humidity and moisture (Tahir & Fahiem, 2014). Thus it is seen that external factors can affect the statistical features of an image. With the large scale acceptance artificial neural networks as efficient feature extractors, it has been applied to fields like occupational stress analysis and prediction (Pandey, Saxena, & Bhatt, 2015) and prediction of inside air temperature of pillar coolers based on parameters like outside temperature, watering and airing (Islam & Morimoto, 2017). Also animal classification systems based purely on convolutional neural networks has also been established (Trnovszký, Kamencay, Orješek, Benčo, & Sýkora, 2017). The comparison of image classification techniques based on CNNs and SVMs establishes that CNNs are better than SVMs with respect to multiclass image classifications (Jawale, 2019).

ARTIFICIAL NEURAL NETWORK , STATISTICAL PARAMETERS AND IMAGE CLASSIFICATION

Artificial Neural Network

An artificial neural network (ANN) is an efficient information processing system which resembles in characteristics with a biological neural network. ANN's possess large number of highly interconnected processing elements called neurons. Each neuron is connected with each other by a connection link. Each connection link is associated with a weight which contains information about the input signal. This information is used by the neural net to solve a particular problem. The neuron computes the weighted sum of all inputs along with their connecting weights and biases. The result is fed into activation function which is fed into next neurons of the next layer. Finally, the output is produced from output layers. The supervised learning is used in classification problems. The error is calculated between target and actual output produced by network based on inputs and weights. The error is reduced by updating the weights of connections among the layers known as training the network. The training is an iterative process and the iteration is stopped either when the maximum value is reached or the error reaches a steady state for successive iterations. The basic structure of a neural network model is depicted in Figure 1.

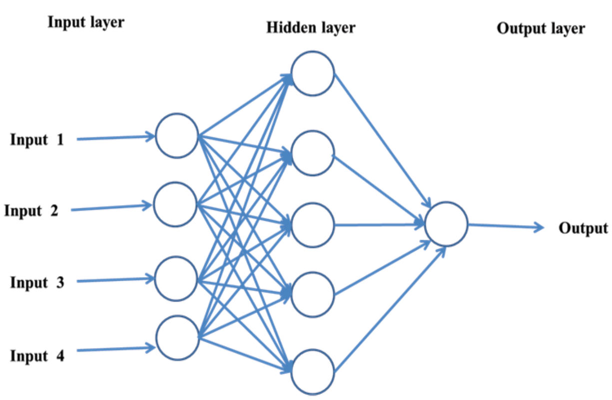

Fig. 1: Artificial Neural Network

Training Algorithm of Artificial Neural Network

In every iteration the weights of the connections associated with inputs and layers are updated until stopping conditions are reached. The connection weights are updated by the guidance of training functions. In this paper, Levenberg-Marquardt algorithm (trainlm) training algorithm is used to update weights of connections. The Levenberg-Marquardt algorithm uses the approximation to the Hessian matrix. The Hessian matrix can be approximated as:

$$H = J^T J$$

And the gradient can be computed as:

$$g = J^T e$$

Where J is the Jacobian matrix that contains first derivatives of the network errors with respect to the weights and biases, and e is a vector of network errors.

The Levenberg-Marquardt algorithm is defined as:

$$x_{k+1} = x_k - [J^T J + \mu I]^{-1} J^T e$$

When the scalar μ is zero, this is just Newton's method, using the approximate Hessian matrix. When μ is large, this becomes gradient descent with a small step size.

Statistical Parameters and HSV Color Components

The various statistical measurements on content and color component of images are computed for classification. The gray scale images are stored as 2D matrix in memory. The details of parameters are furnished in this paper.

H,S and V Components of HSV Color Model

In RGB color model, red, green and blue lights are mixed together in various ratios to reproduce a broad array of colors (Program to Change RGB color model to HSV color model). The artists are used HSV (hue, saturation, value) color model for thinking about a color in terms of hue and saturation and values. The transformation from RGB to HSV as follows:

Algorithm	RGB to HSV color Model
Input	RGB color Model
Output	H,S and V values computed from RGB

Method	Begin
	Step 1
	Divide r, g, b by 255:
	$r = \frac{r}{255}$
	$g = \frac{g}{255}$
	$b = \frac{b}{255}$
	Step 2
	Compute c_{max}, c_{min}, difference
	c_{max}, c_{min}, difference:
	$c_{max} = \max(r, g, b)$
	$c_{min} = \min(r, g, b)$
	$diff = c_{max} - c_{min}$
	Step 3
	Hue calculation:
	if c_{max} and c_{min} equal 0, then
	$h = 0$
	if c_{max} equal r, then compute
	$h = \left(60 * \left(\frac{g-b}{diff}\right) + 360\right) \% 360$
	if c_{max} equal g, then compute
	$h = \left(60 * \left(\frac{b-r}{diff}\right) + 120\right) \% 360$
	if c_{max} equal b, then compute
	$h = \left(60 * \left(\frac{r-g}{diff}\right) + 240\right) \% 360$
	Step 4
	Saturation computation:
	if c_{max} equal 0, then
	$s = 0$
	if c_{max} does not equal 0, then compute
	$s = \left(\frac{diff}{c_{max}}\right) * 100$
	Step 5
	Value computation :
	$v = c_{max} * 100$
	Step 6
	Return h, s and v
	End

Statistical Parameters

Entropy of Image

Entropy is the statistical measurement of randomness and it may be used for characterization the texture of the input image. The entropy of an image is defined as follows:

$$-\sum_{i=0}^{n-1} p_i \log_b p_i \tag{1}$$

where n is the number of gray levels (256 for 8-bit images), p_i is the probability of a pixel having gray level i, and b is the base of the logarithm function.

Standard Deviation

The unbiased estimate of the standard deviation, s_a of the brightness's within a region $(\Re)$ with Λ pixels is called the sample standard deviation (Image Processing Fundamentals) and is given by:

$$S_a = \sqrt{\frac{1}{\Lambda - 1}\sum_{m,n\in\Re}(a[m,n] - m_a)^2}$$

$$= \sqrt{\frac{\sum_{m,n\in\Re} a^2[m,n] - \Lambda m_a^2}{\Lambda - 1}} \tag{2}$$

Mean, Sum, Max and Min of Image

The mean intensity or brightness of an image is defined as the sample mean of the pixel intensities or brightness of image (Garg, M., Malhotra, M., & Singh, H. 2018)). The mean, m_a of the intensities over the Λ pixels of Image is given by:

$$m_a = \frac{1}{\Lambda}\sum_{m,n\in\Re} a[m,n] \tag{3}$$

The min, max and sum of intensities of image are defined by:

$$\tilde{f}(x,y) = \min\{g(r,c) \mid (r,c) \in W\} \tag{4}$$

$$\tilde{f}(x,y) = \max\{g(r,c) \mid (r,c) \in W\} \tag{5}$$

$$\tilde{F}(x,y) = \text{sum}\{g(r,c) \mid (r,c) \in W\} \tag{6}$$

Where g is the gray value or intensity of pixel at location (x, y), r and c are row and column of image size W.

Variance of Image

The general equation for calculating the mean, μ, of a set of numbers, X1 – XN, would be written like this:

$$\mu = \frac{\sum_{i=1}^{N} X_i}{N} = \frac{\sum X}{N} \tag{7}$$

The variance (σ^2) is defined as the sum of the squared distances of each term in the distribution from the mean (μ), divided by the number of terms in the distribution (N) (Variance & Standard Deviation).

Median and Mode

If the pixels are arranged in order either in ascending or descending of their intensities values, the middle value is call median. The image is containing n pixels, the median is written as:

$$Median = \left(\frac{n+1}{2}\right)^{th} pixel, if\ n\ is\ odd$$

Or

$$Median = \left(\frac{n}{2}\right)^{th} pixel, if\ n\ is\ even \tag{8}$$

The mode is the intensity value of pixels of an image which occurs with largest frequencies.

PROPOSED MODEL AND MODULES

Proposed Model for Pig breed Recognition

In this paper, we have proposed the pig breed classification model comprising of a number of sub models in layered structure. Pigs from five different pig breeds were captured from organized pig farms using some restrictions. We have segmented the individual pig images and extracted statistical parameter values and H, S, V color components from the segmented pig images. We have developed the neural network for pig breed named NNPB for fitting the values of statistical parameters and color components with the pig image from five classes. The classification model is used to categorize the output of NNBP module and assigned the class among five classes of Pig breeds. Finally, the breed of pig is declared based on values of statistical parameters and color components of the input pig image as shown in Figure 2.

Fig. 2: Proposed Model for Pig Breed Classification

Pig Image Segmentation

We converted the captured images into equal size. Every pixel of an image was converted to HSV color model. The Hue was determined by keeping the Saturation and Value constant for each breed of pig taken in the study by excluding background of a photo. The HSV image was then converted to binary image with the help of calculated Hue. In the binary image, the visible parts of the pig in original picture turned to white while the background turned to black. The black and white binary image thus obtained might contain some white blobs. The areas of white blobs were measured. Except largest blob, all others blobs were inverted to black to grow a mask image. The obtained mask image was overlapped with original RGB image to get the segmented image of the pig as shown in Figure 3.

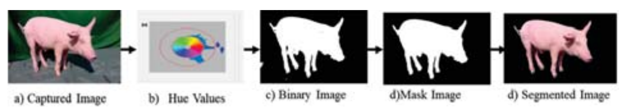

Fig. 3: Hue Calculation and Segmentation of Pig

Neural network for Pig Breeds Classification

To classify breed from pig images, feed forward neural network (known as 'fitnet') is used to fit an input-output relationship. Ten (10) parameter values like hue, saturation, value, entropy, standard deviation, mean, median, mode, sum and variance are calculated from the content of each segmented image from five different breeds. The ten different parameter values are then fed into the network's input layer. One hidden layer with ten neurons and the output layer with one neuron are used in this network. The tangent sigmoid transfer function (tansig) is used at hidden layer and linear transfer function is used at output layer. The Levenberg-Marquardt algorithm (trainlm) training algorithm is used to update weights of connections and maximum iteration is set as 1000 as shown in Figure 4.

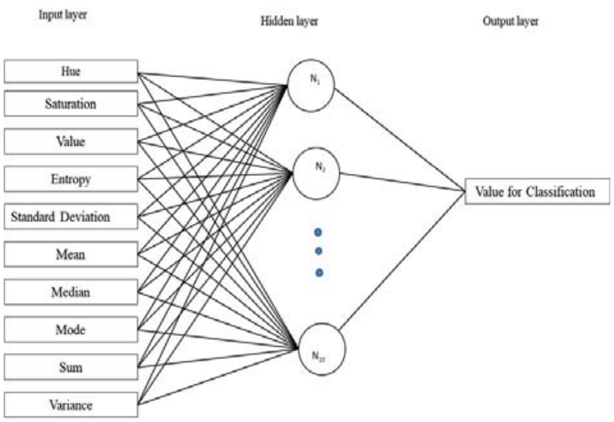

Fig. 4: Neural Network for Pig Breed Classification

Classification module

The supervised neural network is used in this paper. The pig breeds and their class assignments are given in Table 1.

Table 1: Pig Breed and Assigned Class

Sl. No	Pig Breed	Assigned Class
1	Yorkshire	1
2	Duroc	2
3	Ghungroo	3
4	Hampshire	4
5	Mali	5

Algorithm	Class assignment
Input	Output of NNPB module
Output	Class of pig Image

Method	Begin
	If
	Output of NNPB module $\leq$ 1.5
	Then Pig Image is in Class 1
	Else If
	Output of NNPB module > 1.5 && Output of NNPB module $\leq$ 2.5
	Then Pig Image is in Class 2
	Else If
	Output of NNPB module > 2.5 && Output of NNPB module $\leq$ 3.5
	Then Pig Image is in Class 3
	Else If
	Output of NNPB module > 3.5
	& Output of NNPB module $\leq$ 4.5
	Then Pig Image is in Class 4
	Else
	Pig Image is in Class 5
	End

The output of network produces numeric values. The output is categorized for classification of query pig images in classification module. The steps of classification are as follows.

CAPTURING PIG IMAGES AND CREATING PIG BREED IMAGE DATABASE

Capturing of Individual Pig

The images of pigs were captured in such a way that right or left side of their body was clearly visible is shown in Figure 5.

Fig. 5: Capturing the Pig Images

The steps were imposed for capturing the pigs as follows:

1. One green color curtain was placed over standing place and three sides of the pigs to have uniform background.
2. The camera was placed in one side parallel to pigs and keeping about 2 meters distance from it.
3. Lens of camera was hold in a position which was approximately in the middle of the length of the animal perpendicular to the median sagittal plane.
4. The lens was fixed few inches below the height of the animal to snapshot the entire visible parts of a pig.
5. The photos were captured using both smart phones' camera and DSLR camera under natural light in site profile fashion

Pig Image Database

Among the available breed of pig, five breeds, namely; Ghungroo, Mali, Hampshire, Duroc, and Yorkshire (Figure 6) were taken for study. To make use of breeds which are pure, images of individual animals from the said breeds were collected from organized farms, maintained by the premier research institutes of India, namely; 1) ICAR National Research Centre on pig, Rani, Assam, 2) ICAR Research Complex for NEH Region, Umiam, Meghalaya and 3) ICAR Research Complex for NEH Region, Tripura Centre, Tripura.

Fig. 6: Images of Five Pig Breeds with Uniform Background

RESULT AND DISCUSSION

The proposed pig breed classification model is composed of four sub modules as layered structure. The first module takes pig images as input and the classification module assigns class for input images. The result of each module is given separately as follows.

Segmentation of Captured Images

The 50 captured images from each of the five pig breeds named Yorkshire, Hampshire, Duroc, Ghungroo and Mali are used in this paper. All images are fed into the segmentation module and segmented image are produced. The segmented images are used in next layer as inputs. One sample segmented image from each pig breed is shown in Figure 7.

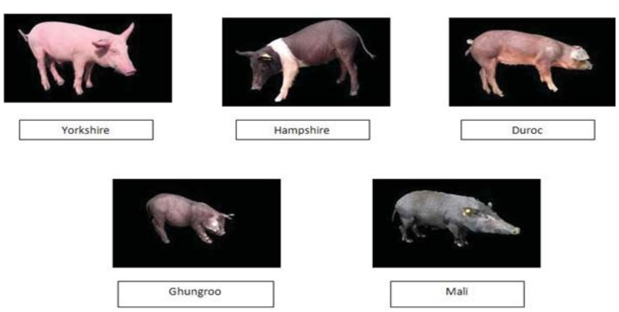

Fig. 7: Segmented Pig Images of Five Pig Breeds

In Figure 7, the background of all images is same and the site profiles are left or right. The background and profiles did not create any problem at the time of extracting statistical and color components from segmented images.

Extracted Values from Statistical Parameters and Color Components

The segmented images from segmentation module are fed into Statistical components and color components retrieval module. The H,S and V color component values are computed using RGB to HSV conversion algorithm. The Entropy, Standard deviation Mean, Median, Mode and Variance are computed using predefined equations. The five pig breeds are assigned into five classes and class are defined numerically as shown in Table 1. The total 250 pigs from 5 pig breeds used in this experiment and ten parameters values from each segmented pig image are extracted. The outputs of this module are furnished as demo tabular form in Table 2. In table 2, extracted data from two segmented pig images from each breed are given and their corresponding breed and class values are furnished.

Breed Classification Accuracy using NNPB module

The extracted data from statistical Parameters and Color Component Retrieval modules as furnished in Table 2 is fed into “Neural Network Pig Breed” neural network. The ten (10) parameter values named hue, saturation, value, entropy, standard deviation, mean, median, mode, sum and variance from each segmented image are used as input and the network produces its class value which is shown in Table 3.

The NNPB network is simulated using Matlab 2016. The NNPB module produced accuracy as 99.89%, 99.66% and 97.54% in training, validation and test respectively. The best performance, regression error plot, Error histogram and training state of NNPB are shown from Figure 8 to Figure 11. The performance of network is shown in Figure 8. It is observed that the MSE error is decreased due to decrease in weights during training by Levenberg-Marquardt backpropagation training algorithm. The blue, green and red lines are shown the MSE for the test, validation and training set, respectively. The best performance of validation is shown at epoch 10 where error is 0.093015. The training of network is stopped at 16 epochs when the validation error reached a steady-state. The regression error plot is given at Figure 9. The data points are represented by circles and the lines represent the best fits between outputs and targets during training, validation and testing. The average R value for training, validation and testing is 0.98783 (≥ 0.93)

represents that the fit is good for pig image classification. Error histogram is presented in Figure 10. The figure demonstrates the distribution of errors with the training, test and validation dataset. It is found that the maximum instances of MSE (around 93) are distributed close to zero line, which is shown by the orange line. Figure 11 depicts the training state of the network up to the moment of stopping. The gradient and μ values are 0.13285 and 0.00001, respectively. It is shown that validation check at epoch 16 has few validation failures.

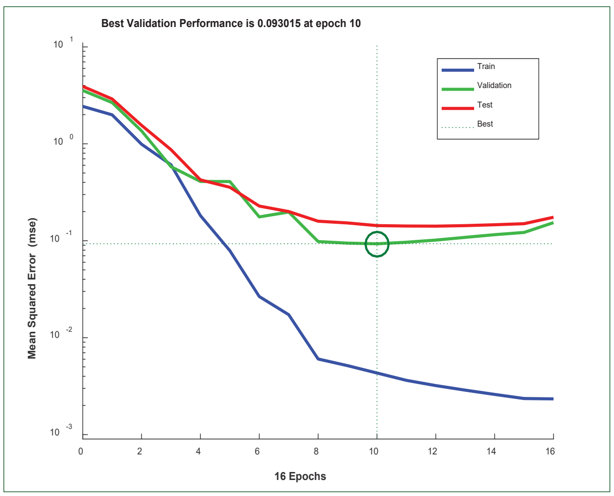

Fig. 8: Performance of Neural Network

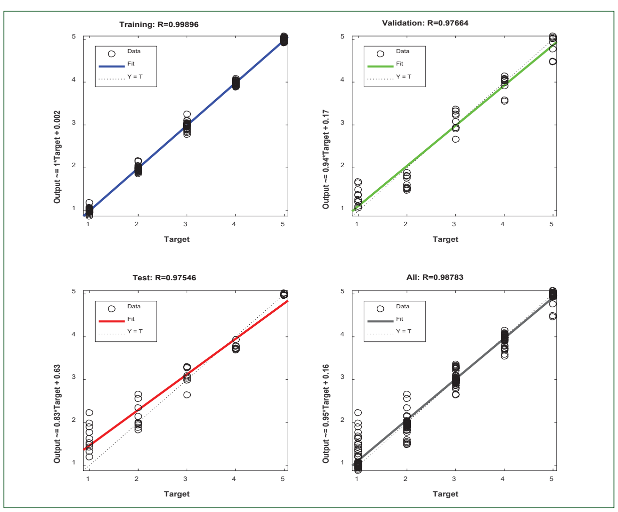

Fig. 9: Training, Test and validation for NNPB

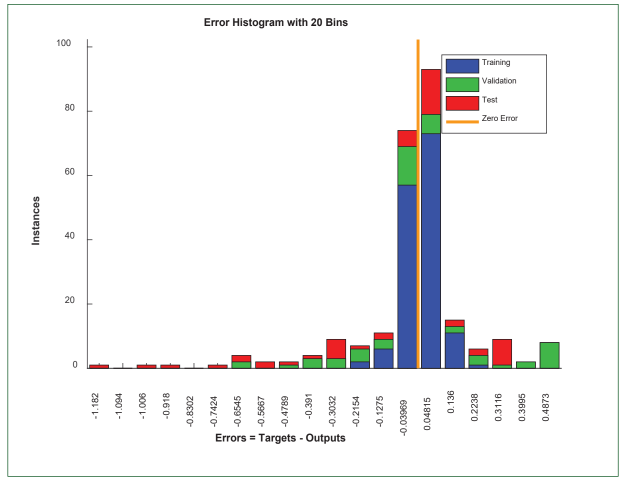

Fig. 10: Network Error Histogram

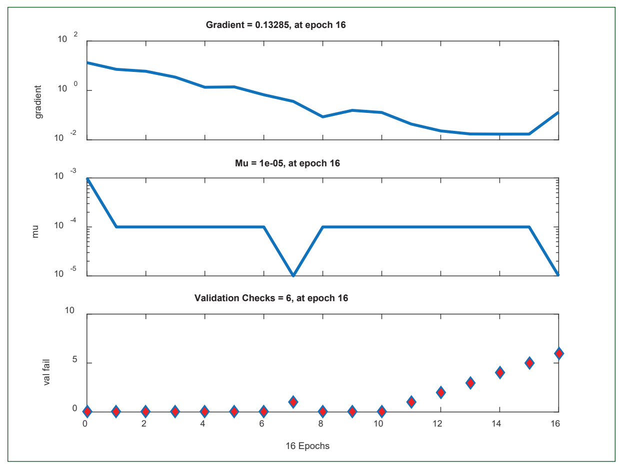

Fig. 11: Network Training State

CLASSIFICATION MODULE AND BREED PREDICTION

The classification module is used for categorizing the output of NNPB network for classification based on algorithm given at section 4.5. 50 images are used to test the trained NNPB network. 10 images from each of the five breeds are used to test the network. The overall accuracy of proposed model is 90% is furnished in Table 4 and graphically represented in Figure 12. The breed wise accuracy graph is given in Figure 13.

Table 2: Classification Result

Sl. No	Pig Breed	No. of Test Images	No. of Classified Successfully	Accuracy (%)
01	Yorkshire	10	07	70
02	Duroc	10	08	80
03	Ghungroo	10	10	100
04	Hampshire	10	10	100
05	Mali	10	10	100
Overall				90

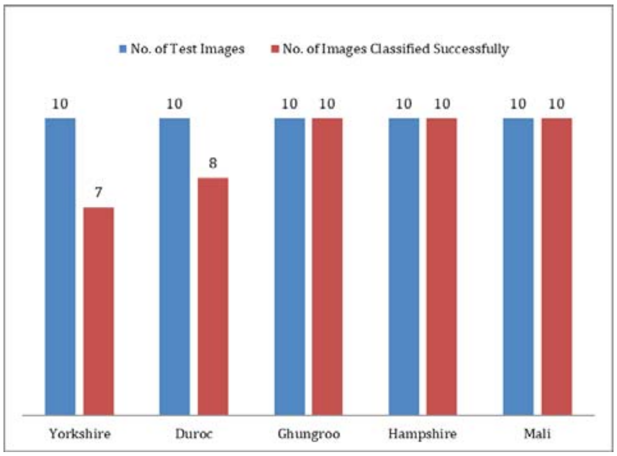

Fig. 12: No of Images Successfully Classified

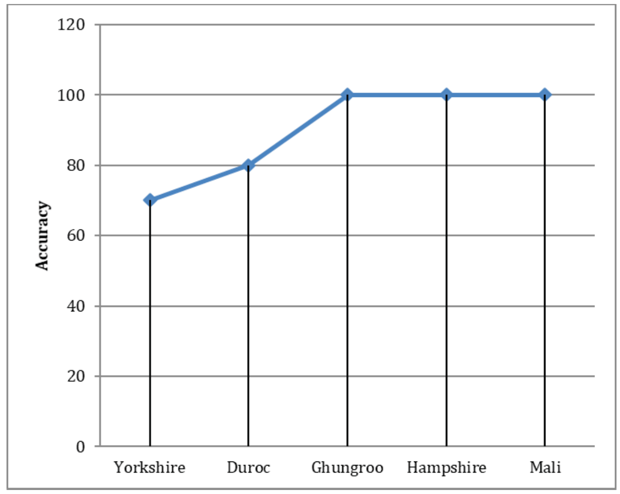

Fig. 13: Classification Accuracy

CONCLUSION

In this paper, Individual pig is classified based on the values of statistical parameters extracted from the content of its image. The individual pig from five pig breeds are captured at organized pig farms using mobile phones. The Levenberg-Marquardt back propagation training algorithm with a minimum mean squared error and maximum correlation coefficient was found to be the best less than 10 epochs. The model is used to predict the breed of 50 pig images and the

Table 3: Statistical Parameter Values

Sl.No	Image ID	H	S	V	Entropy	Std	Mean	Sum	Median	Mode	Variance	Breed	Class Value
1	G1	0.152	0.107	0.074	2.374	24.748	16.342	1863.030	0.000	1.308	6519.171	Ghungroo	3
2	G2	0.145	0.105	0.074	2.290	24.628	16.313	1859.722	0.000	1.278	6635.538	Ghungroo	3
3	Y1	0.336	0.253	0.255	4.132	56.091	53.229	6068.157	0.096	31.222	9582.595	Yorkshire	1
4	Y2	0.278	0.236	0.203	3.516	55.982	41.956	4782.939	0.025	16.606	8683.902	Yorkshire	1
5	M1	0.142	0.062	0.141	3.599	45.877	35.085	3999.646	0.000	10.606	4572.518	Mali	5
6	M2	0.104	0.047	0.112	3.035	35.341	28.077	3200.798	0.000	5.409	4694.001	Mali	5
7	H1	0.224	0.230	0.159	4.112	36.803	33.704	3842.253	0.040	19.449	10009.343	Hampshire	4
8	H2	0.191	0.196	0.153	4.120	36.020	32.382	3691.535	0.010	18.854	9453.684	Hampshire	4
9	D1	0.073	0.259	0.259	4.092	56.073	52.393	5972.768	0.010	33.924	9889.457	Duroc	2
:	:	:	:		:	:	:	:	:	:	:	:	:
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250	D2	0.078	0.305	0.265	4.226	58.881	52.341	5966.879	0.040	27.641	8910.063	Duroc	2

Table 4: Input, Target and Actual Output of NNPB Network

Sl.No	Image ID	H	S	V	Entropy	Std	Mean	Sum	Median	Mode	Variance	Target output	Actual Output
1	G1	0.152	0.107	0.074	2.374	24.748	16.342	1863.030	0.000	1.308	6519.171	3	3.0019
2	G2	0.145	0.105	0.074	2.290	24.628	16.313	1859.722	0.000	1.278	6635.538	3	2.9784
3	Y1	0.336	0.253	0.255	4.132	56.091	53.229	6068.157	0.096	31.222	9582.595	1	0.9932
4	Y2	0.278	0.236	0.203	3.516	55.982	41.956	4782.939	0.025	16.606	8683.902	1	0.9918
5	M1	0.142	0.062	0.141	3.599	45.877	35.085	3999.646	0.000	10.606	4572.518	5	4.9857
6	M2	0.104	0.047	0.112	3.035	35.341	28.077	3200.798	0.000	5.409	4694.001	5	5.0225
7	H1	0.224	0.230	0.159	4.112	36.803	33.704	3842.253	0.040	19.449	10009.343	4	4.0037
8	H2	0.191	0.196	0.153	4.120	36.020	32.382	3691.535	0.010	18.854	9453.684	4	3.9346
9	D1	0.073	0.259	0.259	4.092	56.073	52.393	5972.768	0.010	33.924	9889.457	2	1.9852
:	:	:	:	:	:	:	:	:	:	:	;	:	:
	:	:	:	:	:	:	:	:	:	:	:	:	
250	D2	0.078	0.305	0.265	4.226	58.881	52.341	5966.879	0.040	27.641	8910.063	2	1.8660

prediction accuracy is 90%. Therefore, proposed model can be successfully used for the classification of pig breeds from individual pig images. The images from more pig breeds will be used in this experiment and more classification models will be used in future.

ACKNOWLEDGEMENTS

The authors would like to thank ITRA (Digital India Corporation, formerly Medialab Asia), MeitY, Govt. of India, for funding; Dr. Amitabha Bandyopadhyay, Senior Consultant, ITRA Ag & Food for valuable suggestions; ICAR National Research Centre on pig, Rani, Assam, ICAR Research Complex for NEH Region, Umiam, Meghalaya and ICAR Research Complex for NEH Region, Tripura Centre, Tripura for permitting us to access their organized pig farms and Dr. Sourabh Kumar Das, Principal, Kalyani Government Engineering College for his continuous support.

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