

ANN-BASED CLASSIFIER TRAINED BY BAYESIAN REGULARIZATION FOR WHEAT GRAINS THROUGH COLOUR FEATURE

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ABSTRACT

In this paper, a color feature-based classification of the wheat grains into bread and durum using artificial neural network (ANN) model with bayesian regularization (BR) learning algorithm is presented. Images of 200 wheat grains are taken by a high resolution camera in order to generate the data set for training and testing processes of the ANN-BR model. Data of 3 main colour features (R, G and B) for 200 wheat grains (100 for durum and 100 for bread) are acquired for each grain using image processing techniques (IPTs). Features of R, G and B are separately determined by taking arithmetic average of the pixels within each grain. Several colour features of R/TRGB, G/TRGB, B/TRGB, R-G, G-B and R-B where TRGB is the total of R+G+B are reproduced. Then ANN-BR model input with the 9 colour parameters are trained through 180 wheat grain data and their accuracies are tested via 20 data. The ANN-BR model numerically calculate the outputs with mean absolute error (MAE) of 0.0060 and classify the grains with accuracy of 100% for the testing process. These results show that the ANN-BR model can be successfully applied to classification of wheat grains.

Keywords: Classification, wheat grains, image processing technique, artificial neural network, bayesian regularization learning algorithm

1. INTRODUCTION

Classifying of agricultural products is very important for economic reasons. The wheat grains with different quality are used in making bread, pasta and cakes which are end products. The quality of wheat grain is related to the amount of protein that it possesses. Durum wheat has more protein than the bread wheat. The bread wheat grains mixing into durum grains lead to a reduction in its protein content. Therefore, classification of wheat grains is very important to increase the quality and decrease the cost. Image processing techniques (IPTs) can be employed to classify the products through the visual features. Furthermore, artificial intelligence techniques (AITs) are integrated to the IPTs for classification applications [1-2]. Artificial neural network (ANN), support vector machine (SVM), adaptive neuro-fuzzy inference system (ANFIS), decision tree (DT), K-nearest neighbors (KNN), Naive Bayes (NB) and discriminant analysis (DA) are the most used AITs for classifying agricultural products[3-7]. Over a last decade ANN which is widely used AIT model gains remarkable importance in classification of agricultural grains due to its fast and accurate modeling.

Several works for classifying of various agricultural products have been studied in the literature. Berman et al. classified wheat grains using near infrared hyperspectral image analysis [8]. The efficiencies of the cotton seeds were appointed by classifiers depending on

DT and multilayer perceptron (MLP) by Jamuna et al. [9]. In classification of the wheat and barley seeds, DA and KNN were used to form a classifier [10]. Progressive analysis and meta-multiclass method were employed to classify the wheat grains by Zapotoczny [11]. A study using classifiers and ultraviolet visible spectrophotometry conducted to classify the spice through the KNN [12]. Prakash et al. studied the classification of objects for machine vision implementations with classifier algorithms of the KNN and Naive Bayes [13]. ANN and ANFIS were utilized to classify rice grains into five species with respect to the morphologic features [14]. A MLP-based ANN was modeled by Muñiz-Valencia et al. for classification of coffee grains according to their mineral content [15]. The ANN with the NB was designed by De Oliveira et al. for classification of green coffee grains into four group [16]. It is seen that those proposed classifiers varied among the used techniques, the features of products taken into account and the classification accuracy. Some of them might be difficult to implement while several took into account fewer parameters in classification. Therefore, their mean errors concerning the accuracy of the classification maintained limited.

In this study, a model using ANN with bayesian regularization (BR) [17] learning algorithm is designed to classify wheat grains into bread or durum according to their colour features with high accuracy. The ANN-BR model is built on feed forward back propagation (FFBP) based on multilayer perceptron (MLP). 3 colour features (R, G and B) of 200 wheat grains are acquired for each grain through IPTs for input ANN-BR model. The feature data of 180 grains and 20 grains which are uniformly selected from the total number of 200 grains are respectively employed to train and test the accuracy of the model. The ANN-BR model correctly classifies the wheat grains into durum and bread with 100% for the training and testing process.

2. IMAGE PROCESSING TECHNIQUE

In this section, images are taken and they are imposed to the IPTs to acquire data related to the colour features of the wheat grains in order to model the ANN-BR structure as illustrated in Figure 1. A setup including a computer, a camera and a box arranged by camera holder and a strip LED lighting is used in order to obtain the images. The camera is Logitech C920 CCD having specifications of full HD (1080p), 15 MP, H.264 encoding, Carl Zeiss optics. The photographs are taken by the camera fixed at 35 cm height from the wheat at the bottom of the box which is closed and self-illuminated. The inside of the box is covered with black background.

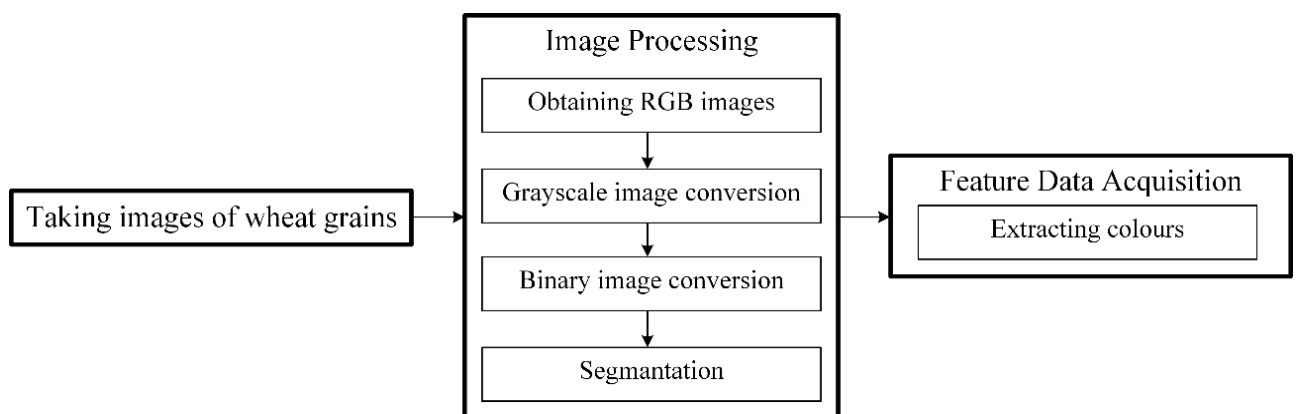


Figure 1. Flowchart of extracting colour features

The images of the wheat grains for bread and durum taken by the camera are illustrated in Figure 2. The bread wheat grain is close to yellow in color, while the durum wheat grain is darker yellow. Therefore, features related to color is considered in this study to model a classifier based on IPT. In order to acquire feature data of the wheat grains (cultivated in Konya, Turkey) for classification, photographs of 100 bread wheat grains (Figure 3(a)) and 100 durum wheat grains (Figure 3(b)) are taken with the high-resolution camera.



Figure 2. The images of the grains for a) bread wheat, b) durum wheat

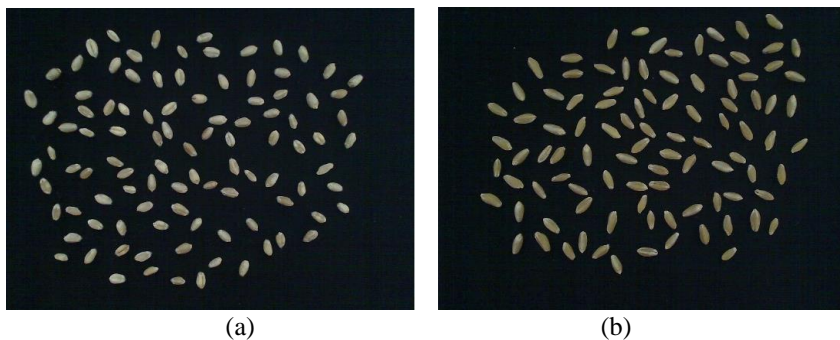
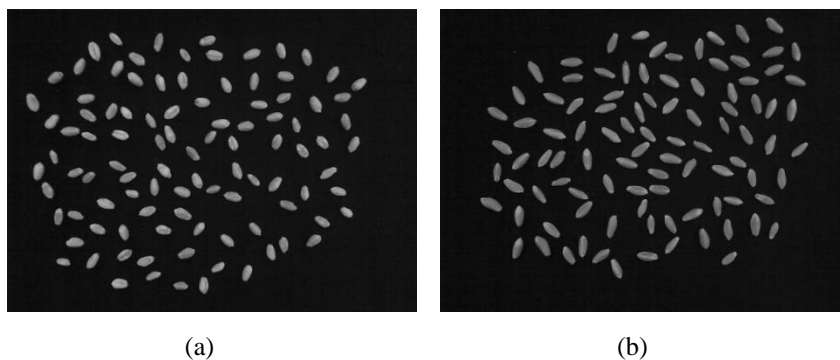


Figure 3. The RGB images of 100 grains for a) bread wheat, b) durum wheat

The IPTs are conducted through MATLAB[®] software to acquire the feature data. Firstly, the RGB level of the each pixel in the images are determined. These images are then converted to grayscale format as shown in Figure 4a and 4b. Secondly, the grayscale images seen from Figure 4c and 4d are converted to binary images (black/white) using Otsu's method [18] in accordance with threshold values of 0.30588 and 0.25882 for bread and durum grains, respectively. Thus the noise of each image is eliminated using morphological process. Thirdly, each grain's position is fixed and they are tagged according to its position through segmentation process.



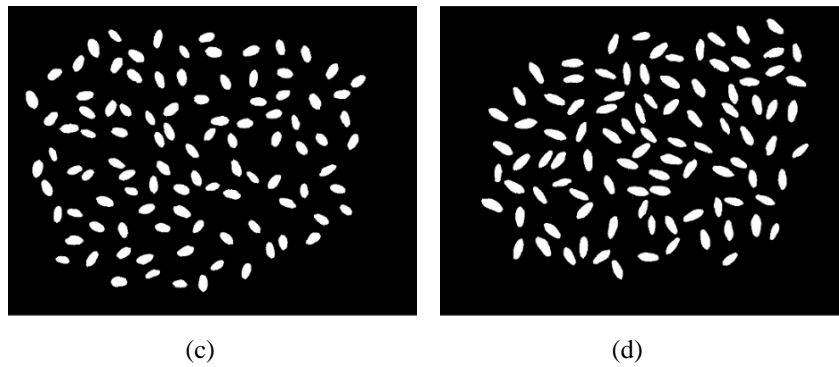


Figure 4. The images of 100 grains for a) grayscale of bread wheat, b) grayscale of durum wheat a) binar images of bread wheat, b) binar images of durum wheat (originally given in Figure 3)

3. DATA ACQUISITION

The visual data related to colour features of each grain is extracted to constitute data set (Table 1). R, G and B in Table 1 are separately determined by taking arithmetic average of the pixels within each grain. Likewise, several colour features of R/TRGB, G/TRGB, B/TRGB, R-G, G-B and R-B where TRGB is the total of R+G+B are reproduced. Colors features of the wheat grains are considered in this study to ANN-BR model.

Table 1. The main and reproduced colour feature data

Input data	Input #	Colour
Main data	3	R, G, B
Reproduced data	6	R/TRGB, G/TRGB, B/TRGB, R-G, G-B, R-B

In Figure 5, 3D scattering of the grains are illustrated to show how durum and bread grains discriminate among each other according to the mentioned colour features. R, G, B from the colour is considered for examining their behavior. It is seen that from the Figure 5 the durum and bread grains cluster distinctly on opposite sides with respect to visual features of colour. This results demonstrate that the durum and bread grains have different features according to colour. Therefore, these colour features can be successfully utilized to classify the wheat grains.

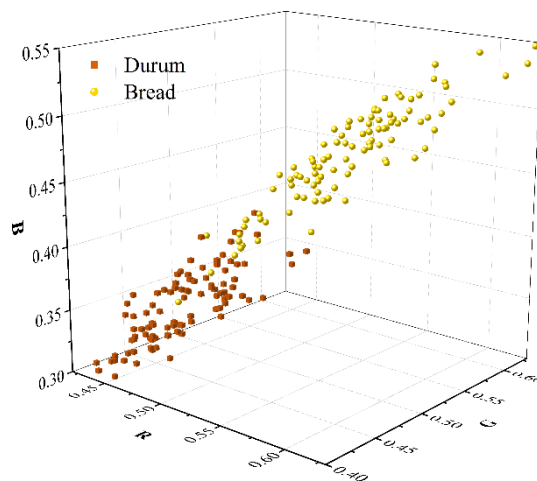


Figure 5. 3D scattering of 100 durum and 100 bread grains according to colour features of R, G and B

4. THE ANN-BR MODEL

Different learning algorithms are used for ANN networks. Some famous type of different backpropagation learning algorithms are Levenberg-Marquardt (LM), Bayesian regularization (BR), cyclical order incremental update (COIU), Powel-Beale conjugate gradient (PBCG), Fletcher-Powell conjugate gradient (FPCG), Polak-Ribiere conjugate gradient (PRCG), one step secant (OSS) and scaled conjugate gradient (SCG) [17]. In this study, the BR algorithm was used in ANN model as learning algorithm. LM and BR are able to obtain lower mean squared errors than any other algorithms for functioning approximation problems. LM was especially developed for faster convergence in backpropagation algorithms. BR learning algorithm updates the weight and bias values according to the LM optimization and minimizes a linear combination of squared errors and weights. It also modifies the linear combination so that at the end of training the resulting network has good generalization qualities.

4.1. Training Process of ANN-BR Model

The main and reproduced color feature data (R, G, B, R/TRGB, G/TRGB, B/TRGB, R-G, G-B and R-B) of the wheat grains were given as inputs and their respective classification results of IPT were given as output to the ANN-BR model. While 180 of 200 data set of wheat grains were employed for training process. After several trials, ANN-BR model based on MLP having one input layer with nine neurons, one hidden layer with five neurons and one output layer with one neuron was constructed, as shown in Figure 6. “Tangent sigmoid” function is used for input and hidden layers while “purelin” function is utilized for output layer. The parameters of the ANN-BR model used in this work are listed in Table 2. The training results are checked according to the following mean absolute error (MAE),

$$MAE = \frac{\sum |Target - Output|}{\text{Number of grains}} \quad (1)$$

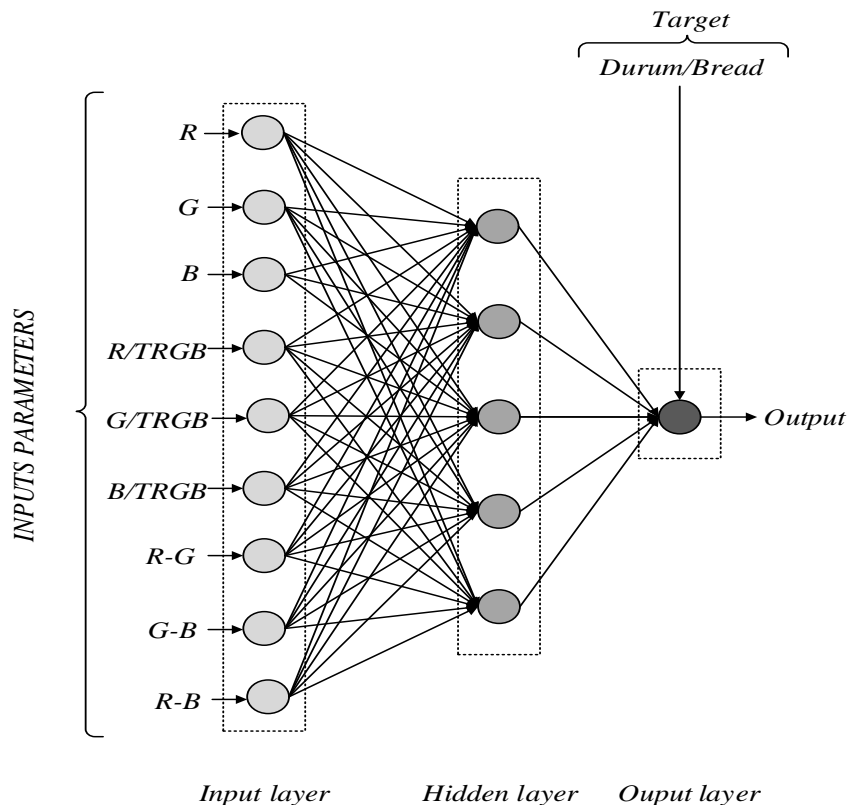


Figure 5. The ANN-BR model for classification of the wheat grains into bread or durum

Table 1. The parameters used to set the ANN model

Parameter	Set type/value
Number of epochs	500
Seed value	1239411541
Minimum gradient descent	10^{-10}
Momentum parameter (μ)	0.00015
μ increment value	5
μ decrement value	0.15
Maximum μ value	10^{10}

4.2. Testing Process of ANN-BR Model

The testing data including 9 colour features of 20 grains (10 bread wheat grains and 10 durum wheat grains) and their testing results are tabulated in Table 2 and Table 3, respectively. As illustrated Table 3, while the number of “1” is assigned to specify durum grains, “2” is appointed to define the bread grains as targets of the ANN-BR model. The ANN-BR model proposed in this study accurately classifies 14 grains with 0 (zero) and 6 grains with very small absolute errors. It demonstrates that the proposed IPT based ANN-BR model can be successfully utilized to classify the wheat grains.

Table 2. The colour features of wheat grains used for testing process

Grain #	Colour features								
	R	G	B	R/TRGB	G/TRGB	B/TRGB	R-G	G-B	R-B
1	0.46401	0.46110	0.37554	0.35675	0.35451	0.28873	0.00291	0.08556	0.08847
2	0.44629	0.42667	0.31442	0.37586	0.35933	0.26480	0.01963	0.11225	0.13187
3	0.45408	0.43612	0.32905	0.37243	0.35770	0.26988	0.01796	0.10707	0.12503
4	0.47520	0.45899	0.38777	0.35947	0.34720	0.29333	0.01622	0.07122	0.08744
5	0.49530	0.46130	0.36418	0.37500	0.34927	0.27573	0.03399	0.09712	0.13111
6	0.49414	0.47737	0.38694	0.36375	0.35141	0.28484	0.01677	0.09043	0.10720
7	0.49538	0.48514	0.40774	0.35684	0.34946	0.29370	0.01024	0.07741	0.08765
8	0.42867	0.41413	0.30537	0.37335	0.36069	0.26596	0.01454	0.10876	0.12331
9	0.46764	0.46611	0.36868	0.35905	0.35788	0.28307	0.00153	0.09743	0.09896
10	0.49530	0.46130	0.36418	0.37500	0.34927	0.27573	0.03399	0.09712	0.13111
11	0.54295	0.55344	0.49124	0.34198	0.34860	0.30942	0.01050	0.06220	0.05170
12	0.56097	0.56472	0.49251	0.34666	0.34898	0.30435	0.00375	0.07222	0.06847
13	0.54778	0.53283	0.45383	0.35699	0.34725	0.29576	0.01495	0.07899	0.09395
14	0.50643	0.49885	0.41525	0.35651	0.35117	0.29232	0.00758	0.08361	0.09119
15	0.57530	0.57505	0.49077	0.35055	0.35040	0.29904	0.00025	0.08428	0.08453
16	0.53829	0.54708	0.48991	0.34171	0.34729	0.31100	0.00879	0.05718	0.04838
17	0.55437	0.54975	0.47757	0.35049	0.34757	0.30194	0.00463	0.07217	0.07680
18	0.53307	0.55278	0.48354	0.33967	0.35223	0.30810	0.01971	0.06925	0.04954
19	0.53343	0.54038	0.47404	0.34463	0.34912	0.30626	0.00695	0.06634	0.05939
20	0.52088	0.54294	0.46972	0.33966	0.35405	0.30630	0.02207	0.07322	0.05116

Table 3. The testing results of classifying the wheat grains with the ANN-BR model

Grain #	Results			
	IPT results	ANN-BR results	Absolute errors	Classification
1	1.0000	1.0000	0.0000	Durum
2	1.0000	1.0000	0.0000	Durum
3	1.0000	1.0000	0.0000	Durum
4	1.0000	0.9810	0.0190	Durum
5	1.0000	0.9994	0.0006	Durum
6	1.0000	1.0000	0.0000	Durum
7	1.0000	1.0342	0.0342	Durum
8	1.0000	1.0000	0.0000	Durum
9	1.0000	1.0000	0.0000	Durum
10	1.0000	0.9994	0.0006	Durum
11	2.0000	2.0000	0.0000	Bread
12	2.0000	2.0000	0.0000	Bread
13	2.0000	2.0000	0.0000	Bread
14	2.0000	2.0580	0.0580	Bread
15	2.0000	2.0000	0.0000	Bread
16	2.0000	2.0000	0.0000	Bread
17	2.0000	2.0000	0.0000	Bread
18	2.0000	2.0000	0.0000	Bread
19	2.0000	2.0000	0.0000	Bread
20	2.0000	2.0000	0.0000	Bread
MAE			0.0060	
Accuracy				100%

5. CONCLUSION

In this article IPT based ANN-BR model is proposed for accurate classification of the wheat grains into bread and durum. The ANN-BR model based upon the MLP with three layers is designed for this purpose. 3 main and 6 reproduced colour features are acquired for 100 bread and 100 durum wheat grains. The ANN-BR model is trained with 180 grains and its accuracy is tested through 20 grains of 200 wheat grains data. The ANN-BR model classify the wheat grains with the MAE of 0.0060 for testing process. The ANN-BR model correctly classifies the wheat grains into durum and bread with 100 % for the training and testing process. The proposed method can be easy integrated to the industry to automatically classify the agricultural grains.

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