Exploring the best model for sorting Blood orange using ANFIS method

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Abstract: Orange has abundant nutritional properties and is consumed worldwide. Sorting oranges of different masses based on their physical traits could help reduce packaging and transportation cost. The 'Blood' cultivar of Iranian oranges from Kermanshah province of Iran (7.03 °E 4.22 °N) was used in this study. 100 samples were randomly selected. During the two-day experiment, all measurements were carried out inside the laboratory at mean temperature of 24°C. In this study, some physical properties of 'Blood' orange were measured, such as length, width, thickness, volume, mass, mean value of geometric diameter, sphericity and projected area. ANFIS and linear regression models were employed to predict the mass based on sphericity and mean of projected area inputs. In ANFIS model, samples were divided into two sets, with 70% for training set and 30% for testing set. The coefficient of determination (R^2) for ANFIS and linear regression models were 0.983 and 0.927, respectively. It is shown that the mass can be estimated based on ANFIS model better than linear regression model.

Keywords: linear regression, orange, packaging, physical properties, sorting

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1 Introduction

Proper sorting system with a low error rate can be useful in packaging products in the most optimized way, and is therefore important in handling, packing and marketing. Before packaging operation, an appropriate model based on mass can be useful in grading that could be approached by statistical or artificial intelligence models. Iran is one of the countries with the longest history in producing citrus fruits, but unfortunately has not succeeded in grading them. Most citrus fruits have been packed and no separate operations are done to record their quality or size. However, it is necessary to design and develop accurate systems for grading oranges in terms of weight, volume and internal-external quality. One of the goals for mass sorting is to put relatively identical fruits in separate packages so as to minimize losses due to fruit movement in transportation. Annual production of the citrus in Iran is 3.5 million tons, ranking the sixth in the world. Physical characteristics of fruits are important factors to consider when designing systems of grading, conveying, processing, and packaging (Omid et al., 2010). These physical properties include mass, volume, mean of geometric diameter, length, diameter, surface area, sphericity, projected area, static coefficient of friction (Topuz et al., 2005). Soltani and his colleagues conducted a study on banana fruits. They developed an equation based on estimated projected area and measured projected area. The coefficient of determination (R^2) was found 0.978 (Soltani et al., 2011). An equation based on three geometric dimensions was developed by Spreer and Muller to calculate the mass of the mangoes. The coefficient of determination (R^2) was

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obtained 0.97 (Spreer and Müller, 2011). Surface area and volume of axi-symmetric of agricultural products could be measured by using machine vision (Khojastehnazhand et al., 2009). Khoshnam and his colleagues developed an equation based on minor diameter to calculate the mass of the pomegranate. The coefficient of determination (R^2) and equation were found 0.91 and $M = 0.06C^2 - 4.11C + 143.5$, respectively (Khoshnam et al., 2007). The relationship between surface area of bergamot was investigated by functioning physical attributes such as dimensional characteristics and projected areas (Keramat Jahromi et al., 2007) and the coefficient of determination (R^2) was 0.92. In the other research, the mass model for date fruit was found based on its volume. The coefficient of determination (R^2) and equation were found 0.76 and $M = +0.796V + 1.3930$ respectively (Keramat Jahromi et al., 2007). The mass of kiwi fruit was estimated based on its physical properties (Lorestani and Tabatabaeefar, 2006). Ertekin and colleagues reported several physical properties of plum fruits (Ertekin et al., 2006). Several physical properties of four orange varieties (Alanya, Finike, W. Navel, and Shamouti) were determined such as length, diameter, volume, sphericity, surface area, mass, geometric mean diameter and projected area (Topuz et al., 2005). A mathematical model was devised to analyze the non-destructive pepper fruit volume (Kadri Bozokalfa and Murat, 2010). The correlation coefficient (R) between the fruit volumes and the prediction of the model was 0.9516. Al-Maiman and Ahmad determined physical properties. Some physical properties such as surface areas, dimensions and volume were investigated for pomegranate fruit (Al-Maiman and Ahmad, 2002) and models of predicting pomegranate fruit mass were found.

Adaptive neuro fuzzy inference system (ANFIS) is a neural network based on Takagi-Sugeno fuzzy inference system. It has the benefits of both neural networks and fuzzy logic principles. The inference system of ANFIS is composed of fuzzy IF–THEN rules that are able to learn from nonlinear functions (Abraham, 2005). Thus, ANFIS is considered as a universal estimator (Jang et al. 1997).

Since the orange size is more relevant to its mass, it is applied in this study. This research aims to use image processing technique and ANFIS for determination of mass based on physical properties to assess the feasibility of using this technique for mass prediction, non-destructively. Such methodology is novel and there exist no report in the literature. Therefore, the idea behind of this research is original.

The objectives of this study are to obtain the best model of sorting system with lower error and to compare the modeling validity of ANFIS and linear regression methods in this case study.

2 Materials and methods

In this research 100 samples of 'Blood' orange were purchased from different local in different days to obtain enough variability (Figure 1). The oranges were transported to physical laboratory of Faculty of Agriculture Engineering from University of Razi in Kermanshah. All experiments were carried out at a natural temperature (24°C) in two days.

Figure 1 Photographs of 'Blood' orange

The mass of each orange (M) was measured by a digital balance with accuracy of ±0.1 g. Linear dimensions, i.e. length (L), width (W), thickness (T), were measured by a digital caliper with a sensitivity of 0.01 mm. Mean of geometric diameter (D_g), sphericity (S) and ellipse area (A) were calculated by using the following Equation (1), Equation (2) and Equation (3) (Li et al., 2011):

$$D_g = (LWT)^{1/3} \quad (1)$$

$$S = (LWT)^{1/3}/L \quad (2)$$

$$A = \pi LW^3 \quad (3)$$

Image acquisition system that is shown in Figure 2 was used to get the projected areas. The volume of 'Blood' orange was determined by the water displacement method (Aydın and Özcan, 2007). The weight of each orange was determined using a digital balance with ±0.1 g accuracy. The orange was placed into a measuring cylinder with specified water volume so that the fruit did not float during immersion in water; weight of water displaced by the fruit was determined. The volume of each fruit was calculated by Equation (4) (Mohsenin, 1986).

$$V = W/\rho \qquad (4)$$

where, V is the volume, cm^3; W is mass of displaced water, kg; and ρ is water density, kg cm^{-3}.

Figure 2 Apparatus for measuring dimensional characteristics (area meter Delta-Tengland)

2.1 ANFIS

Membership functions parameters of ANFIS model have been set by the back propagation algorithm in combination with the least squares method. The structure of the fuzzy system has been learned from data sets. Important options that have been considered include: the type of input fuzzy sets - the number of fuzzy sets - the type of output fuzzy set - the type of optimization techniques and the number of epochs. Membership functions types of ANFIS are: triangular (trimf), trapezoidal (trapmf), generalized bell (gbellmf), gaussian (gausamf) and sigmoidal (sigmf) shapes.

Fuzzy inference system is shown in Figure 3. The fuzzy inference system is composed of four functional blocks (Singh et al., 2012).

(i) A knowledge base, containing some fuzzy rules and database, which defines the rules of used membership functions in the fuzzy section.

(ii) An inference engine, which performs the inference operations on the rules.

(iii) A fuzzification interface, which transforms the crisp inputs into degrees of match with linguistic values.

(iv) A defuzzification interface, which transforms the fuzzy results of the inference into a crisp output (Bagheri et al., 2012).

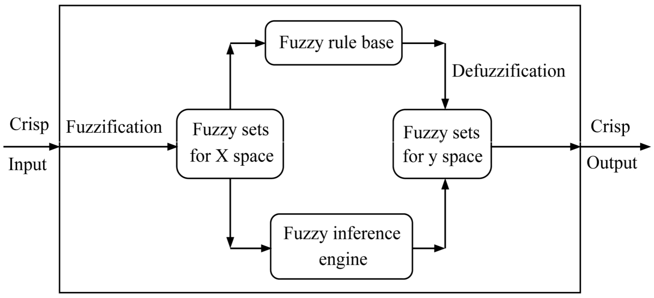

Figure 3 Block diagram of fuzzy inference system

Figure 4 shows the structure of ANFIS for two input variables (Yurdusev and Firat, 2009). In layer 1, the membership values of the numerical inputs for the fuzzy sets were computed. In layer 2, the firing strengths of the fuzzy rules were determined. In layer 3, nodes compute the normalized fuzzy rule strengths. In layer 4 derives the inferred output. Then in layer 5, aggregate the inferred outputs to derive the required crisp output as stated (Tan et al., 2011). In this study 100 samples of 'Blood' orange were tested by the system. The data were divided into two sets: 70% as training data and 30% as testing data.

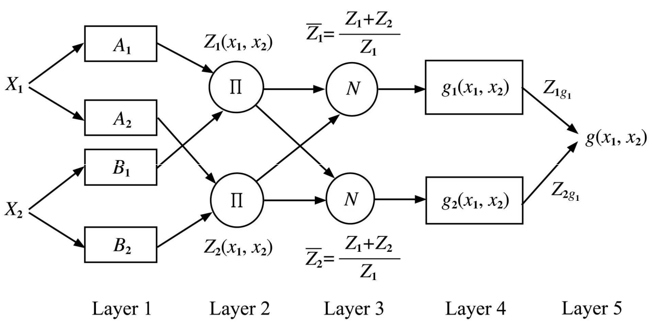

Figure 4 The structure of ANFIS for two input variables

3 Results and discussion

ANFIS and linear regression models of 'Blood' orange based on some properties have been presented in Table 1 and Table 2, respectively. Among seven models in Table

1, model 1, which had two inputs of P and S, had the highest coefficient of determination (R^2) value. The R^2 value for this case was found 0.983. Among seven models in Table 2, the highest R^2 value was 0.927 for the models of 1 and 7 that is lower than ANFIS results. Therefore, it can be seen that neural-fuzzy method is better than linear regression in SPSS software. Hence, sorting can be done at higher accuracy based on ANFIS method.

Table 1 Summary of some ANFIS models for the mass of 'Blood' orange

No	Mf Input	Mf Number	Epoch Number	Mf Output	Input1	Input2	Input3	R^2	SSE	MSE
1	gbellmf	2 2	10	linear	P	S	-	0.983	68.56	2.9
2	trimf	2 2	1000	constant	D_g	P	-	0.934	299.15	9.9
3	trimf	2 2 2	100	constant	L	W	P_W	0.933	403.82	13.4
4	trimf	2 2 2	250	constant	L	W	T	0.913	441.68	14.7
5	trimf	2 2 2	10	constant	L	W	P_T	0.904	295.96	9.9
6	Gausa2mf	2 2 2	10	linear	L	W	P_L	0.884	747.70	24.9
7	trimf	3 3 3	125	constant	L	W	P	0.826	695.63	23.9

Note: P: Criteria projected areas; S: sphericity; D_g: geometric mean diameter; L: length; W: width; P_W: projected area perpendicular to width; T: thickness; P_T: projected area perpendicular to thickness.

Table 2 Summary of some linear regression models for the mass of 'Blood' orange

No	input			Regression equation	R^2	SSE	MSE
	1	2	3				
1	P	S	-	$M = 0.041A_P + 0.016S - 48.186$	0.927	936.26	9.65
2	D_g	P	-	$M = 0.034D_g + 0.00A_P - 34.831$	0.925	960.08	9.89
3	L	W	P_W	$M = 0.023L + 2.056W + 0.366P_W - 113.771$	0.911	1133.08	11.80
4	L	W	T	$M = 1.329L + 1.901W + 1.498T - 171.081$	0.904	1227.58	12.79
5	L	W	P_T	$M = 0.022L + 1.370W+1.254P_T - 118.794$	0.910	1149.97	11.98
6	L	W	P_L	$M = 0.029L + 1.648W + 0.049P_L - 91.657$	0.903	1239.98	12.92
7	L	W	P	$M = 0.038L + 0.145W + 0.774P_T - 75.626$	0.927	935.06	9.74

Note: P: Criteria projected areas; S: sphericity; D_g: geometric mean diameter; L: length; W: width; P_W: projected area perpendicular to width; T: thickness; P_T: projected area perpendicular to thickness; P_L: projected area perpendicular to length.

The relation between the training error of the network and number of epochs in ANFIS model is shown in Figure 5. From this Figure, error is decreased when the number of epochs raises and finally levels off (Naderloo et al., 2012). Figure 6 shows the best ANFIS structure for the mass modeling of 'Blood' orange based on two inputs (P and S). From Figure 6 it can be seen that model has two inputs, four rules and one output.

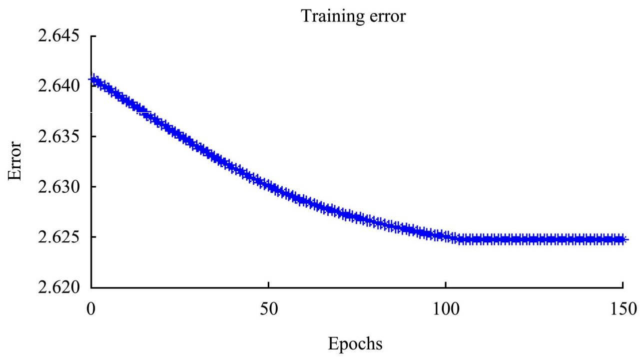

Figure 5 The relation between training error and the number of epochs

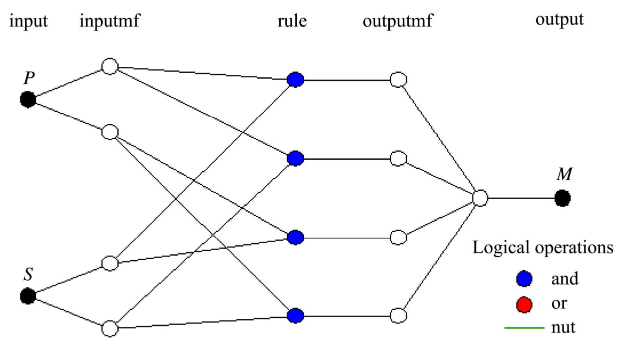

Figure 6 General structure of the model

ANFIS rules structure is shown in Figure 7. In this Figure three diagram of first row are indicative the premise and results of the first rule. Each rule is a row of diagrams and each column is a variable. Number of rules is shown on the left sides of diagrams. The yellow diagrams in the first and second columns are indicative membership functions of the rules premise. The blue diagram in third column is indicative membership functions of the rule result. The last diagram represents the massive aggregation decisions in the third column. The final decision has depends on the input values. The defuzzification output has been shown as a thick vertical line on this diagram. When the user changes input values by moving the red lines, the system produces output values automatically, as seen in last column of the figure (Güneri et al., 2011). As two membership functions are assigned for each input, the model presents $4(2^2)$ different rules to produce the output value. When the rule structure is analyzed, the output value raises parallel to get results from the input selection phase. Figures 8 and 9 show the first membership functions of the input parameters that were derived by training through the "dsigmf" membership function (Daoming and Jie, 2006).

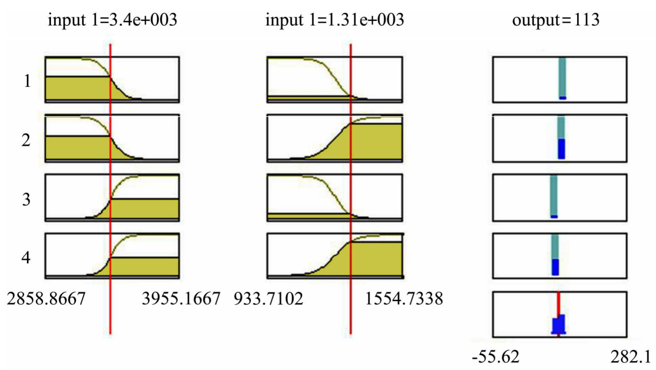

Figure 7 The structure of ANFIS rules

In Figure 8 and Figure 9, it is considered that the membership function of P (input 1: Criteria projected areas) was almost the same as that of S (input 2: Sphericity). Figure 10 and Figure 11 depict the variations in the values predicted by ANFIS networks against two inputs (P and S). The mass value rises by rising in P and falls by decreasing in S. From Figure 11 it can be seen that P input has a greater impact on the value prediction by ANFIS network (mass) rather than S input.

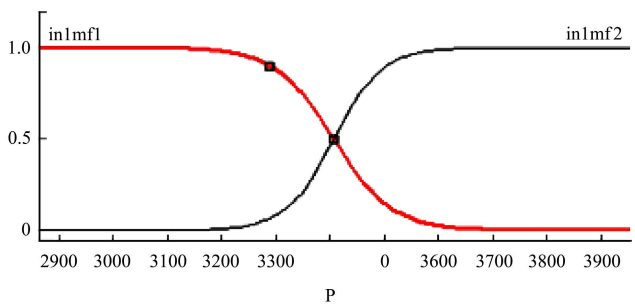

Figure 8 Membership functions for the input of criteria projected areas

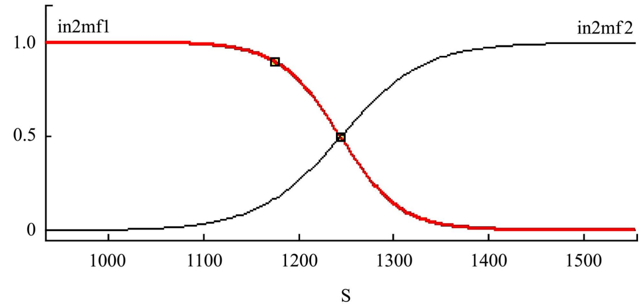

Figure 9 Membership functions for input sphericity (S)

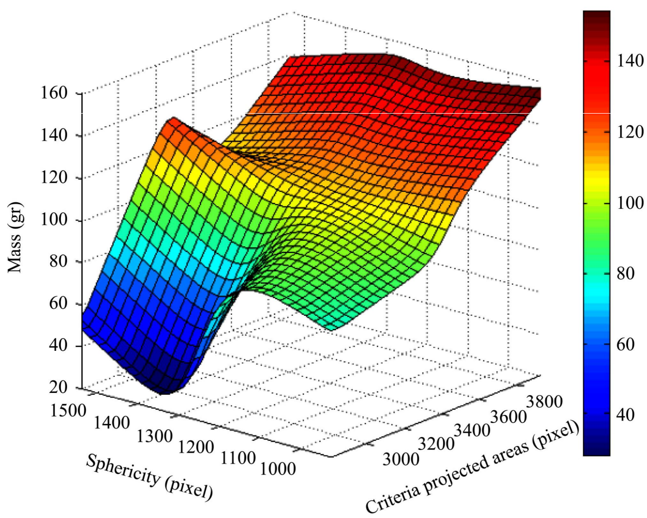

Figure 10 Mass variations of the 'Blood' orange versus two inputs (P, S)

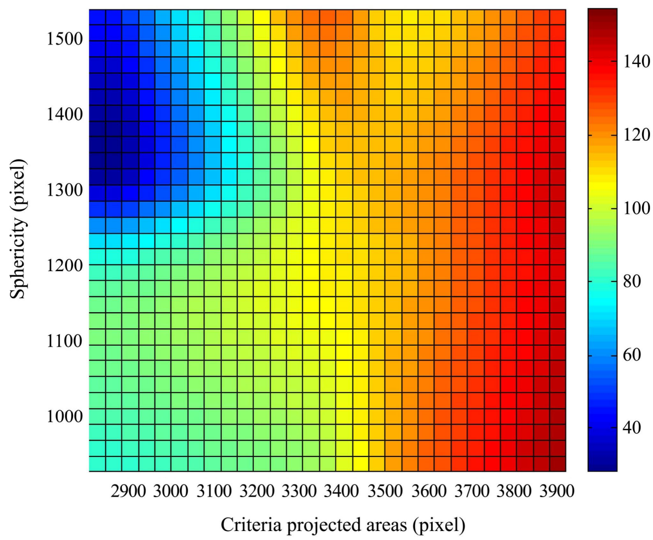

Figure 11 Mosaic Graph of the best ANFIS model

4 Conclusion

In this research, the potential of ANFIS model for mass estimating of the 'Blood' orange has been investigated and compared with the well-known statistical method of linear regression technique. For developing

ANFIS models, 70% of experimental data (randomly selected) were used for training and 30% (the residual data) were used for testing these models.

1) For developing ANFIS model, different learning algorithms with different epochs were experimented to define the model which has best potential of estimation ability to predict experimental results.

2) A best correlation was found through two inputs of criteria projected areas (P) and sphericity (S).

3) After finding the best ANFIS model, results of ANFIS and linear regression were compared.

4) In compression of ANFIS and linear regression models, the statistical parameters of determination coefficient (R^2), SSE and MSE were used as evaluation criteria.

5) The values of R^2, SSE and MSE were 0.983, 68.56 and 2.85 for the best model of ANFIS and 0.927, 936.258 and 9.652 for the best model of linear regression, respectively.

Nomenclature

L	length (mm)
w	width (mm)
T	thickness (mm)
D_g	geometric mean diameter (mm)
S	sphericity (dimension less)
P_A	projected area (mm^2)
A	ellipse area (mm^2)
$S_{ellipse}$	surface area of ellipsoidal shape (mm^2)
ρ	water density (kg cm^{-3})
W_W	weight of displaced water (kg)
P_L	projected area perpendicular to length (mm^2)
P_W	projected area perpendicular to width (mm^2)
P_T	projected area perpendicular to thickness (mm^2)
P	Criteria projected areas (mm^2)
V	volume (cm^3)

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