International Journal of Livestock Research, Vol. 11 (1) Jan' 2021
http://www.ijlr.org
eISSN: 2277-1964
NAAS Rating 2020 – 5.36

Original Research

# The Relationship Between the Coat Colors of Kars Shepherd Dog and its Morphological Characteristics Using Some Data Mining Methods

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**How to cite this paper:** Celik, S., & Yilmaz, O. (2021). The Relationship Between the Coat Colors of Kars Shepherd Dog and its Morphological Characteristics Using Some Data Mining Methods. *International Journal of Livestock Research*, 11(1), 53-61. http://dx.doi.org/10.5455/ijlr.20200604072222

**Received** : May 26, 2020
**Accepted** : Sep 29, 2020
**Published** : Jan 31, 2021



## Abstract

*The aim of the study was to apply various data mining techniques to determine coat colour and live weight of Kars shepherd dog. C5.0, MARS (Multivariate Adaptive Regression Splines) and Bagging MARS (Bootstrap Aggregating Multivariate Adaptive Regression Splines) were used in the study. The coat colours were pied, black, brown, white and Roan. The age range of the 52 shepherd dogs were between 2 and 8. Morphological characteristics were live weight (LW), withers height (WH), rump height (RH), body length (BL), chest circumference (CC), chest depth (CD) and front shinbone length (FSL). Verification rate of C5.0 algorithm to determine the coat of the dog was found 71.2%. R2 (determination coefficient), Adjust R2, Root-mean-square error (RMSE), Standard deviation ratio (SDratio), Mean absolute percentage error (MAPE) and Akaike Information Criteria (AIC) values of MARS algorithm estimating live weight were as follows: 0.845, 0.828, 2.893, 0.393, 5.047 and 122 respectively. Same statistics for Bagging MARS algorithm were 0.893, 0.881, 2.4, 0.326, 4.158 and 101 respectively. It was observed that data mining methods have revealed correct results according to goodness of fit statistics.*

**Keywords:** Body Morphological Features, Coat Colors, Data Mining, Dog

## Introduction

People benefit from dogs in various ways. They are primarily used for hunting, protecting the herd and for wardership as a hobby. Police and military institutions use dogs for patrol companion, search and rescue and as an explosive and drug detector. Dogs are used in the search and rescue operations in case of natural disasters such as earthquakes and avalanche. (Dirlik, 2008).

Kars Shepherd dogs are precious dogs with more than 600 years of history shepherding horse and cattle in the high mountains on the northeast of Turkey. They are very protective and pedigreed dogs being resistant to cold weather and coherent to mountainous terrain. They are very clever and ideal shepherd dog breeds. They have mixed and fluffy coat with strong legs and big and strong paws. Their protective characteristics are at a high level whereas they are able to use their combative paws against the enemy. Being used for wardership and protecting the herd, these dogs have an average lifespan of 10-12 years and an average weight of 75-110 kg for males and 60-100 kg for females. The average length is 70-100 cm for males and 65-90 cm for females (Anonymous, 2018). Kars Shepherd dog takes the first place in terms of exercise need, energy level, brushing need, accessibility, wardership, protection, friendship, endurance to hot and cold according to a study on USA Pitbull-Terrier and Anatolian shepherd dog (Anonymous, 2010). Kars Shepherd dog is generally raised in the North-eastern Anatolia in Turkey (Kırmızıbayrak, 2004). It is common in Artvin, Ağrı, Ardahan, Erzurum, Iğdır, Kars and Van provinces (Yılmaz, 2008). They are seen in various colours generally plain black, plain white, grey, red, blonde or brown. They are not very friendly animals and have a very rough nature. Their average adult weight is 45.3±1.17 kg for males and 43.3±2.00 kg for females. Their average shoulder length is 72.6±0.78 cm for males and 71.9±1.55 cm for females (Yılmaz and Ertuğrul, 2012). The purpose of raising Kars Shepherd dogs commonly performed in Turkey has been disappearing due to the migration from rural to urban areas and the decrease in the bovine and ovine animals in the rural (Yılmaz and Ertuğrul, 2012b). The Kars Shepherd Dog is a concervancy dog with a herd of cows, a flock of sheep and goat, but it is not a herding dog. The main duty of Kars dog is to protect the flock, its owner/shepherd and his property from predators and to avoid intruders. This breed is the potential dangers of strangers. Kars Dogs are very tough, healthy and strong dogs. They do not appear to suffer too many illnesses because of good adaptation ability in harsh climate and geographical condition of East Anatolia (Yılmaz, 2007).

It is important to make live weight estimation and coat colour by using statistical methods for the individuals in need to make more conscious and rationalist decision. The aim of this study was to determine the coat of the dog by using C5.0 algorithm and to make an estimation for live weight by considering body measurements, age, gender and raised district using MARS and Bagging MARS algorithm.

## Material and Method

The Kars Shepherd Dogs in this study were surveyed between October 2010 and February 2011 in the provinces of Agri (39º43'N; 43º03'E), Ardahan (41º07'N; 42º42'E), Artvin (41º11'N; 41º50'E), Erzurum (39º54'N; 41º16'E), Igdir (39º55'N; 44º03'E), Kars (40º35'N; 43º06'E), and Van (38º30'N; 43º21'E) (www.googleearth.com). A total of 52 dogs, 34 male and 18 females, was worked. These dogs were aged between 2 and 8 years, and divided into five coat colors (Pied, Black, Brown, White and Roan) groups. In the Pied group there were 8 males and 4 females; in the Black group there were 8 males and 3 females; in the Brown group there were 11 males and 5 females; in the White group there were 3 males and 3 females; and in the Roan group there were 4 males and 3 females. The ages of the dogs were determined from the information given by their owners. Besides, more previous in "short communication" study comparison was performed of the phenotypic traits of Turkish Kars (Caucasian) dogs for different sexes, regions, ages and coat colors by (Yilmaz and Ertugrul, 2012a).

C5.0 algorithm is a new decision tree algorithm developed from C4.5. Keeping all the functions of C4.5, C5.0 present more new technologies. One of important technologies is boosting, and another one is the building of a cost-sensitive tree (Su-lin and Ji-zhang, 2009). To performed decision tree and pruning technology in C4.5 algorithm initial, it is taken the given samples set as the root of decision tree. Next, it is computed information gain ratio of every attribute of the training samples, and it is selected the attribute with the highest information gain ratio as the split attribute. Then, it is repeated the steps above for every subset it has created until all the subsets can satisfy one of the following conditions (Su-lin and Ji-zhang, 2009).

- All the samples in the subset belong to one class.

- All the attributes of the subset have been transacted and there are no attributes left which can be used to divide data set.
- All the testing attributes left of the samples in the subset have the same value.

MARS (Multivariate Adaptive Regression Splines) algorithm, was proposed by Friedman (1991) in order to study the non-linear relationships between input variables and output variable(s). For the MARS algorithm, no assumptions about functional relationships between dependent and input variables are needful. It is a nonparametric statistical method that takes a basis for a divide. The splines are linked smoothly to each other and, basis functions as piecewise curves provide analysts to flexibly model linear and non-linear effects (Zhang and Goh, 2016).

The MARS algorithm builds models from two sided truncated functions of the predictors (x) of the form:

$$(x-t)_+ = \begin{cases} x-t, & x > t \\ 0, & otherwise \end{cases}$$

These serve as basis functions for linear or nonlinear expansion that approximates some true underlying function *f(x)*.

The MARS model for a dependent (outcome) variable *y*, and M terms, can be summarized in the following equation:

$$y = f(x) = \beta_0 + \sum_{m=1}^{M} \beta_m H_{km}(X_{v(k,m)})$$

where the summation is over the M terms in the model, and $\beta_0$ and $\beta_m$ are parameters of the model (along with the knots *t* for each basis function, which are also estimated from the data) (Hastie *et al.*, 2001). Function H is defined as:

$$H_{km}\left(X_{v(k,m)}\right) = \prod_{k=1}^{K} h_{km}$$

where $X_{v(k,m)}$ is the predictor in the k'th of the m'th product. For order of interactions K=1, the model is additive and for *K=2* the model pairwise interactive (Friedman, 1991).

The so-called Generalized Cross Validation error is a measure of the goodness of fit that takes into account not only the residual error but also the model complexity as well. It is given by (Kornacki and Ćwik, 2005).

$$GCV(\lambda) = \frac{\sum_{i=1}^{n}\left(Y_i - \hat{Y}_i\right)^2}{\left[1 - \frac{M(\lambda)}{n}\right]^2}$$

Here: *n* is the number of samples in the study, $Y_i$ is the observed value of the response variable, $\hat{Y}_i$ is the predicted value of the response variable, $M(\lambda)$ is the penalty function for the complexity of the model containing λ terms. MARS predictive model with interaction term was constructed based on the lowest GCV (Akin *et al.*, 2020).

Bagging method was first used by Breiman (1994). Bagging is used as a tool to form a more stable classifier. Bagging predictors is a method to generate multiple versions of a predictor. Multiple versions of the bootstrap replication is formed by a set of data.

To comparatively test the estimate criteria of MARS, the following goodness of fit criteria were determined (Willmott and Matsuura, 2005; Liddle, 2007; Takma *et al.*, 2012):

1. Pearson correlation coefficient (r) between the actual and predicted dependent variable values
2. Coefficient of Determination

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2}{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}$$

3. Adjusted Coefficient of Determination

$$Adj.R^2 = 1 - \frac{\frac{1}{n-k-1}\sum_{i=1}^{n}\left(Y_i - \hat{Y}_i\right)^2}{\frac{1}{n-1}\sum_{i=1}^{n}(Y_i - \bar{Y})^2}$$

4. Root-mean-square error (RMSE) given by the following formula

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2}$$

5. Standard deviation ratio ($SD_{ratio}$)

$$SD_{ratio} = \sqrt{\frac{\frac{1}{n-1}\sum_{i=1}^{n}(\varepsilon_i - \bar{\varepsilon})^2}{\frac{1}{n-1}\sum_{i=1}^{n}(Y_i - \bar{Y})^2}}$$

6. Mean absolute percentage error (MAPE)

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{Y_i - \hat{Y}}{Y_i}\right|.100$$

7. Akaike Information Criteria (AIC)

$$AIC = nlog\left(\frac{\left(Y_i - \hat{Y}_i\right)^2}{n}\right) + 2k$$

## Results and Discussion

Descriptive statistics of body morphological characteristics of Kars shepherd dog are presented in Table 1.

**Table 1:** Introductory features of body measurements of Kars Shepherd dog different coat colors

| Variable | Sex | Pied | | Black | | Brown | | White | | Roan | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N | $\bar{X} \pm s_{\bar{x}}$ | N | $\bar{X} \pm s_{\bar{x}}$ | N | $\bar{X} \pm s_{\bar{x}}$ | N | $\bar{X} \pm s_{\bar{x}}$ | N | $\bar{X} \pm s_{\bar{x}}$ |
| LW | M | 8 | 47.3±2.96 | 8 | 43.6±2.18 | 11 | 44±2.21 | 3 | 44.3±2.85 | 4 | 49±2.35 |
| | F | 4 | 41.5±3.66 | 3 | 38.3±1.86 | 5 | 42.2±2.71 | 3 | 47.3±5.78 | 3 | 48.3±8.95 |
| WH | M | 8 | 73.4±1.76 | 8 | 71.3±1.36 | 11 | 72.9±1.70 | 3 | 71.3±2.19 | 4 | 74.3±1.44 |
| | F | 4 | 71.5±3.30 | 3 | 66.3±2.19 | 5 | 71.6±3.19 | 3 | 75.3±2.33 | 3 | 75.3±5.46 |
| RH | M | 8 | 72±1.95 | 8 | 71.5±1.07 | 11 | 71.1±1.64 | 3 | 70.7±1.86 | 4 | 72.8±1.38 |
| | F | 4 | 69.5±3.50 | 3 | 64±2.52 | 5 | 70±3.13 | 3 | 73.7±2.40 | 3 | 75±6.66 |
| BL | M | 8 | 89±1.51 | 8 | 89±1.98 | 11 | 84.5±2.49 | 3 | 79±5.03 | 4 | 87.3±3.09 |
| | F | 4 | 86.3±3.15 | 3 | 84±1.15 | 5 | 88.4±3.25 | 3 | 95.7±3.84 | 3 | 90.3±8.41 |
| CC | M | 8 | 84.1±1.85 | 8 | 84.1±2.22 | 11 | 85.3±1.59 | 3 | 88.3±2.33 | 4 | 87±4.42 |
| | F | 4 | 83.5±3.01 | 3 | 77.3±0.88 | 5 | 81.2±2.37 | 3 | 89±3.61 | 3 | 89±5.51 |
| CD | M | 8 | 31.8±0.45 | 8 | 31.4±1 | 11 | 31.6±1.01 | 3 | 30.3±1.2 | 4 | 31.8±0.95 |
| | F | 4 | 30.6±1.31 | 3 | 30.2±0.44 | 5 | 30±1 | 3 | 32.2±1.92 | 3 | 31.7±2.89 |
| FSL | M | 8 | 11.3±0.39 | 8 | 11.7±0.43 | 11 | 12.1±0.30 | 3 | 12.3±0.67 | 4 | 12.1±0.72 |
| | F | 4 | 12.4±0.24 | 3 | 11.5±0.29 | 5 | 12.3±0.26 | 3 | 12.5±0.5 | 3 | 12.5±0.76 |
| Age | M | 8 | 5.63±0.68 | 8 | 3.75±0.70 | 11 | 4.55±0.41 | 3 | 5±1.73 | 4 | 5.50±0.65 |
| | F | 4 | 3.75±1.44 | 3 | 4.33±0.88 | 5 | 4±0.78 | 3 | 5±1 | 3 | 4.33±0.33 |

*$\bar{X}$: Mean, $s_{\bar{x}}$: Standard error mean, LW: Live weight, WH: Withers height, RH: Rump height, BL: Body length, CC: Chest circumstance, CD: Chest depth, FSL: Front shank length.*

The graphic including correlation coefficient among morphological characteristics of Kars Shepherd Dog is given in Figure 1. When Figure 1 is examined, all correlations except for the correlation coefficient between CD and FSL having the lowest correlation (r=0.134) are statistically significant (p<0.05, p<0.01 and p<0.001). The highest correlation is between RH and WH and its coefficient is r=0.952. It is followed by the correlation between LW-RH (r=0.811) and LW-WH (r=0.785). Briefly, a high correlation is found among LW, WH and RH for dogs.

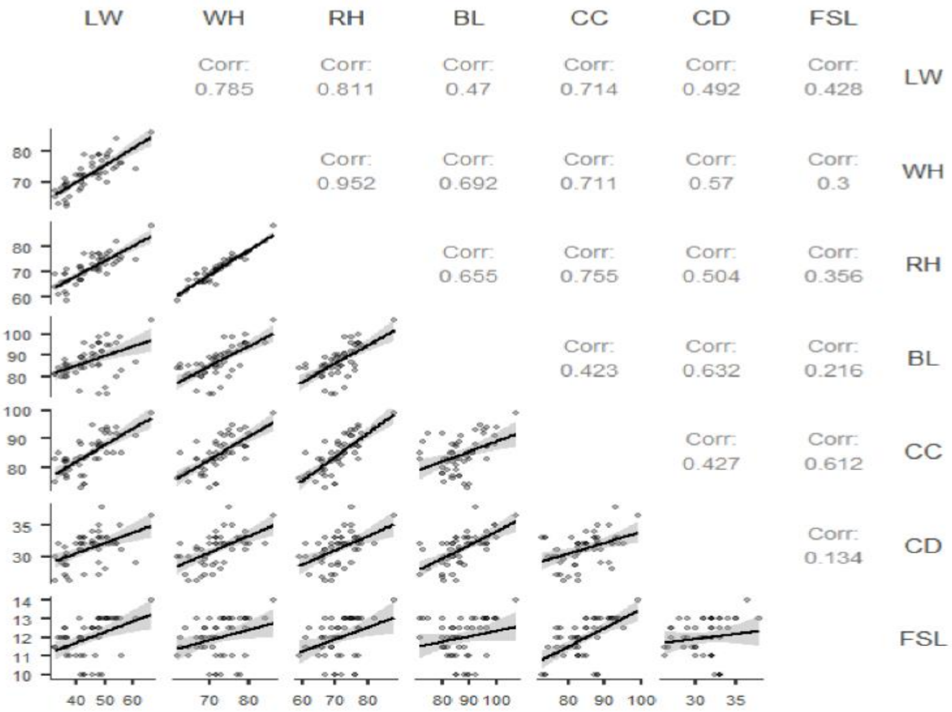

**Figure 1:** Corelation coefficient and plots

C5.0 algorithm was used to determine age, gender and various body morphological characteristics of the coats. The error rate of this algorithm was 28.8% and accuracy rate was 71.2%. C5.0 algorithm tree is shown in Figure 2.

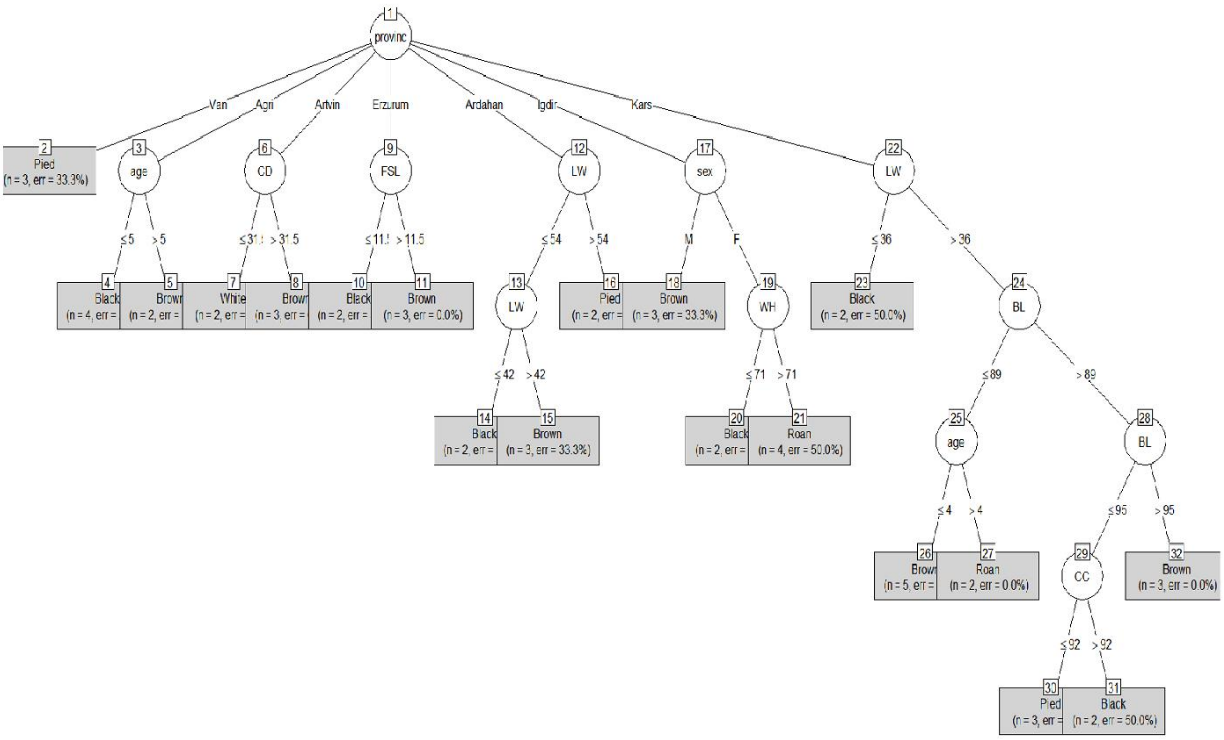

**Figure 2:** Parameters adjusted C5.0 algorithm decision tree model

The results of this algorithm presented in Figure 1 are summarized as follows.

If province="Van" then "Pied"
If province="Ağrı" and age ≤ 5 then "Black"

If province="Ağrı" and age > 5 then "Brown"
If province="Artvin" and CD ≤ 31.5 then "White"
If province="Artvin" and CD > 31.5 then "Brown"
If province="Erzurum" and FSL ≤ 11.5 then "Black"
If province="Erzurum" and FSL > 11.5 then "Brown"
If province="Ardahan" and LW > 54 then "Pied"
If province="Ardahan", LW ≤ 54 and LW ≤ 42 then "Black"
If province="Ardahan", LW ≤ 54 and LW > 42 then "Brown"
If province ="Iğdır" and sex=Male then "Brown"
If province ="Iğdır", sex=Female and WH ≤ 71 then "Black"
If province ="Iğdır", sex=Female and WH > 71 then "Roan"
If province ="Kars" and LW ≤ 36 then "Black"
If province ="Kars", LW > 36, BL ≤ 89 and age ≤ 4 then "Brown"
If province ="Kars", LW > 36, BL ≤ 89 and age > 4 then "Roan"
If province ="Kars", LW > 36, BL > 89 and BL > 95 then "Brown"
If province ="Kars", LW > 36, BL > 89, BL ≤ 95 and CC ≤ 92 then "Pied"
If province ="Kars", LW > 36, BL > 89, BL ≤ 95 and CC > 92 then "Black"

Results of the prediction equation applied using MARS and Bagging MARS algorithms are showed in Table 2. The desirable predictive attribute of the MARS equation applied here was founded with providing the smallest GCV=8.58. The observed values in Kars Shepherd Dog were established very strongly with those predicted by the MARS algorithm (P<0.001) as a live weight estimation modeling. For prediction equation of MARS model with 6 terms, was found $R^2$ estimate (0.845). The standard deviation ratio of 0.393, Adj. $R^2$ of 0.828, RMSE of 2.893, MAPE of 5.047, and AIC of 122 represented that the MARS model capturing two influential factors in other words live weight in dogs had a good fit. In the MARS algorithm, the Pearson correlation coefficient between real and predicted values was 0.919 (P<0.01). The coefficients in the prediction equation were founded significant (P<0.05, P<0.001). The prediction equation for MARS algorithm was found as and parameter coefficients were displayed in Table 2.

**Table 2**: MARS algorithm parameter estimation

| | **Estimate** | **Std. Error** | **t-value** | **Pr(>\|t\|)** |
|---|---|---|---|---|
| **(Intercept)** | 36.4778 | 0.7695 | 47.404 | < 2e-16 *** |
| bx[, -4]h(RH-67) | 1.5985 | 0.2491 | 6.417 | 6.27e-08 *** |
| bx[, -4]h(FSL-12) | 6.4007 | 1.2535 | 5.106 | 5.87e-06 *** |
| bx[, -4]h(WH-73) | -1.2858 | 0.3537 | -3.636 | 0.000686 *** |
| bx[, -4]provincArdahan*h(12-FSL) | 8.9935 | 3.521 | 2.554 | 0.013942 * |

*LW = 35.1 - 1.29 * max (0, WH - 73) + 1.47 * max (0, RH - 67) + 2.31 * max (0, 12 - FSL) + 8.78 * max (0, FSL - 12) + 9.15 * province Ardahan * max (0, 12 - FSL)*

If the withers height is higher than 73 cm, a decrease of 1.29 kg in weight is expected. If the back height is higher than 67 cm, an increase of 1.47 kg in weight is expected. When FSL ≤ 12 cm, the live weight increases to 2.31 kg. When FSL > 12 cm, the increase is expected to be 8.78 kg. The live weight of the dogs raised in Ardahan having FSL ≤ 12 cm is expected to increase up to 9.15 kg. The plot between the predicted and observed LW value is illustrated in Figure 3 for MARS algorithm.

Various values are given to independent variable such as body morphological characteristics, gender and coat colour to estimate live weight. For example, for WH=70, RH=69, BL=90, CC=89, CD=30, FSL=12.6, age=6, province="Ardahan", sex="M", hide="White"; LW=35.9 kg was found.

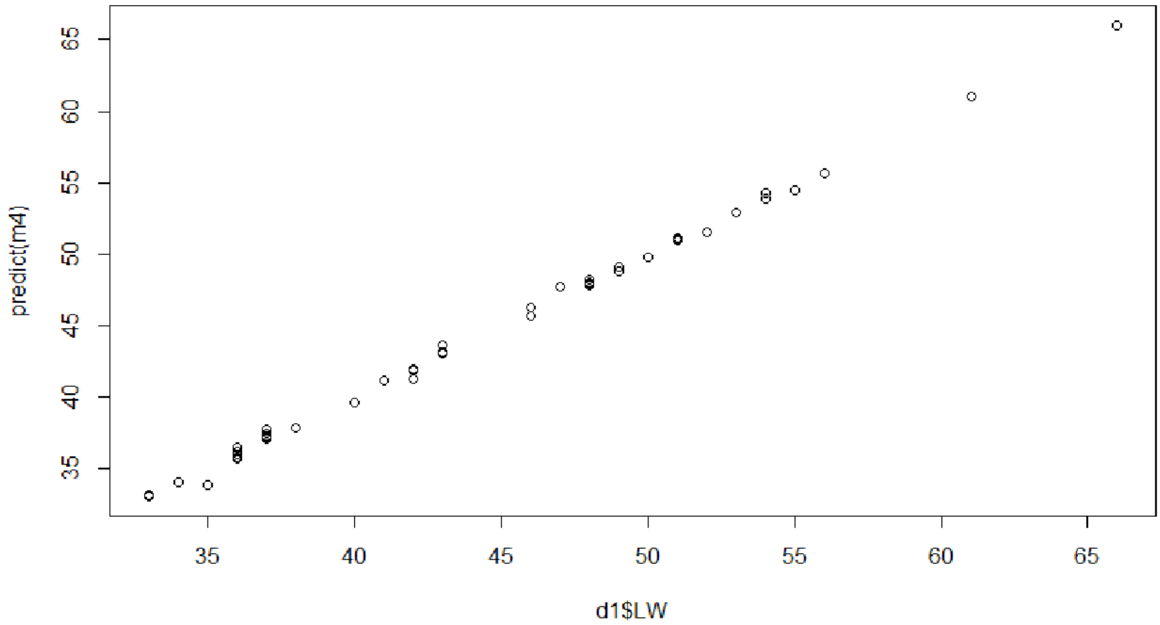


**Figure 3:** The concurrence between predicted and observed LW values

The prediction equation of the Bagging MARS algorithm as below.
LW=(44.75737

- 4.440197 * hide White - 1.184047 * h(6-age) - 0.6092315 * h(73-WH)
+ 0.572592 * h(RH-69) + 0.9929349 * h(81-BL) + 1.138674 * h(CC-88)
- 2.013275 * h(29-CD) + 1.375165 * province Ardahan*h(RH-69)
+ 35.37875
- 2.191864 * h(5-age) - 2.590617 * h(age-5) + 2.579835 * h(RH-69)
- 2.275638 * h(RH-74) + 1.460395 * h(82-BL) + 2.022128 * h(BL-82)
- 2.431245 * h(BL-86) + 2.090841 * h(12.5-FSL) + 10.66348 * h(FSL-12.5)
- 0.5555426 * sex M*h(BL-86) - 0.8969211 * h(74-RH)*hide White
+ 32.06046
+ 3.755911 * h(WH-69) - 3.830848 * h(WH-71) + 0.4705838 * h(RH-66)
+ 0.987543 * h(80-CC) + 0.5756246 * h(CC-80) + 1.795891 * h(29-CD)
- 0.9106166 * h(CD-29) + 2.702094 * h(11.5-FSL) + 3.050703 * h(FSL-11.5)
+ 0.6829513 * province Igdir*h(WH-71) - 0.06599902 * age*h(CC-80)
- 0.6478695 * age*h(11.5-FSL) + 0.7359805 * sex M*h(CD-29) ) / 3

According to this equation, on the first bootstrap, live weight decrease is expected for the ones with white coat, younger than the age of 6 and having WH ≤ 73 cm and CD ≤ 29 cm. The effect of the decrease on the model is as follows; -4.44, -1.184, -0.609 and -2.013 respectively. Positive effects are as follows; when RH > 69 cm, 0.573, BL ≤ 81 cm, 0.993, CC > 88 cm, the effect is 1.139 and for the ones raised in Ardahan having RH > 69 cm, the effect is 1.376. In other words, positive effect means an increase in live weight. Results on the second and third bootstrap can be interpreted similarly.

In the second bootstrap, when the highest live weight increase is FSL > 12.5, the effect is 10.663 and the highest negative effect is -2.431 with BL > 86. In the third bootstrap, the highest positive effect is 3.756 with WH > 69 cm and the highest negative effect is -3.831 with WH > 71 cm. Among Bagging MARS goodness of fit models, r, $R^2$, Adj. $R^2$, SDratio, RMSE, MAPE and AIC were found as 0.945, 0.893, 0.881, 0.326, 2.4, 4.158 and 101 respectively. If its standard ratio value is 0.40 or 0.10, then a regression model applied had a good fit or a very good fit was underlined that by Grzesiak and Zaborski (2012). The plot between the predicted and observed LW values is showed in Figure 4 for Bagging MARS algorithm.

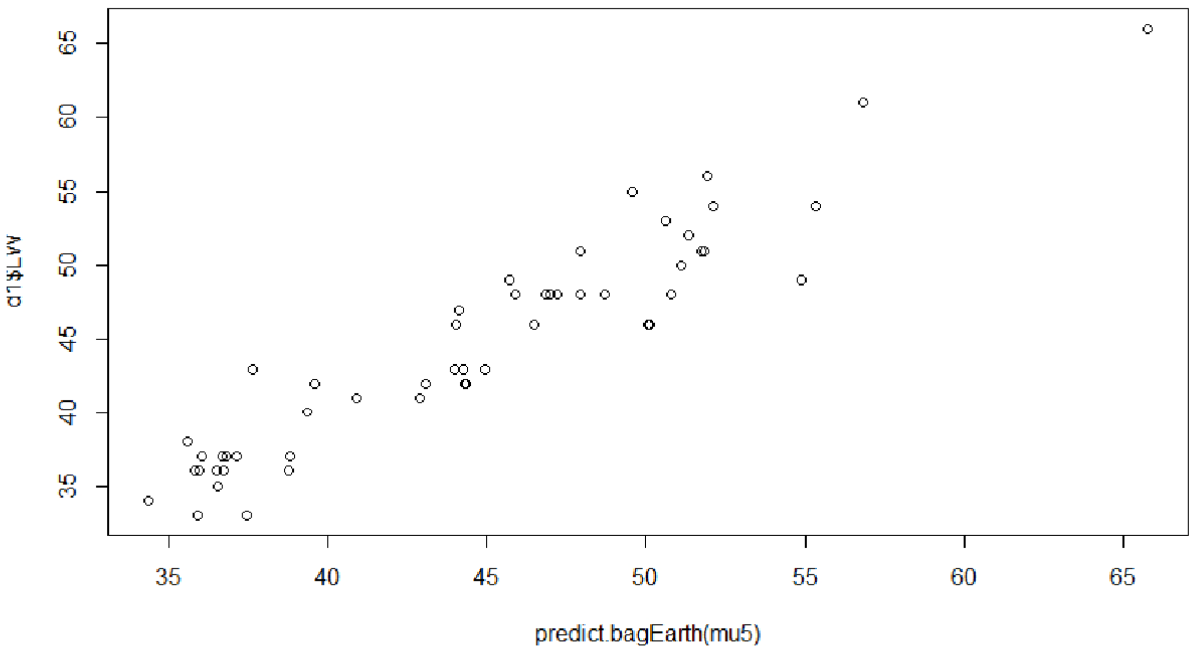


**Figure 4:** The concurrence between predicted and observed LW values

Various values are given to independent variable such as body morphological characters, gender and coat colour to estimate live weight in the Bagging MARS model similar to MARS model. For example, for WH=70, RH=69, BL=90, CC=89, CD=30, FSL=12.6, age=6, province="Ardahan", sex="M", hide="White"; LW=35.9 kg was found. The estimated LW values were found to be same in MARS model and in Bagging MARS model. It has been observed that Bagging MARS algorithm presents better results compared to MARS algorithm according to the goodness of fit criteria.

## Discussion

In a data mining study on the relationship between body weight and other characteristics in dogs, CHAID, Exhaustive CHAID and CART algorithm were applied in the live weight estimation of 208 Sivas Kangal dogs. In the CHAID algorithm considered as the most appropriate the results were as follows; $R^2$(%)=71.575, Adj. $R^2$(%)=70.727, SD ratio=0.533, RMSE=4.966 and MAPE=9.858. The highest live weight was calculated as 61.375 kg in the ones with rump height higher than 80 cm and front shinbone length higher than 14 cm (Çelik and Yilmaz, 2017). It was found that the methods used in this study were better according to goodness of fit statistics. In another study, body weight estimation was performed for 122 Turkish Greyhound dogs using various body measurements. CART and MARS models were applied and $R^2$=0.9193, Adj. $R^2$=0.8983, $SD_{ratio}$=0.2840 and RMSE=0.6041 were found in MARS model revealing better results (Çelik and Yilmaz, 2018). It was found to be better than the results of the present study in terms of the suitability of the method. Elmaz *et al.* (2018) examined the changes of body measurements in time using repeating analyse of variance (ANOVA). The authors analysed the effect of main age on the Head Length, Head Girth, Ear Length, Chest Girth, Tail Length, Body Length, Shoulder Height, Rump Height, Front wrist girth and Back wrist girth variables on the $10^{th}$, $38^{th}$ and $52^{nd}$ days. All variables showed significant changes in accordance with the time and age as the result of the analysis.

## Conclusion

For addressing the classification problem, C5.0 algorithm was used to conclude which is the most satisfactory for the specific structure of the problem. The decision tree approach in C5.0 algorithm displayed satisfactory results in classifying the predefined structure with an average of 71.2% of accuracy in supervised classification. The predictive performances of the models created using MARS and Bagging MARS algorithms were obtained very close to each other. However, Bagging MARS algorithm has been found to be a more suitable method. Based on the empirical results using Bagging MARS approach, the best model of live weight prediction is the model with the GCV value of 5.328 and the value of $R^2$ is 0.893%. The most significant influencing predictor of the live weight is FSL.

## Conflict of Interests

There is no conflict of interest.

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