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A fuzzy rule-based system for predicting the live weight of Holstein cows whose body dimensions were determined by image analysis

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Abstract

The aim of this study was to determine the body measurement of Holstein cows through image analysis (IA) and to estimate their live weight (LW) by means of a fuzzy rule-based model using the body measurements. For this purpose, a photography environment was established at a dairy cattle farm where a large number of cows were kept. First, digital photographs of each animal were synchronously taken from different directions with Canon EOS 400D cameras. At the same time, body dimensions, namely wither height (WH), hip height (HH), body length (BL), and hip width (HW), of the cows were manually measured using a laser meter and measuring stick. The LWs of the cows were found with a weighing scale and the data were automatically saved on a computer. In the second stage, the photos were analyzed by IA software developed in the Delphi programming language and body measurements were computed. Manually measured values were very close to IA results. Finally, a fuzzy system was developed by using these body measurements. This fuzzy system was developed by using MATLAB software. Weights that were estimated with the developed knowledge-based system were compared with those found by the platform scale. The correlation coefficient was calculated (r = 0.99). There was a statistically meaningful relationship between the compared data. The developed system can be used confidently, and the system on which the experiments were performed can be modeled successfully.

Key Words: *Digital image analysis, fuzzy rule base, body dimension, live weight*

1. Introduction

Nowadays, numbers and capacities of dairy cattle farms have increased, so computer-based studies in the management of the farms grow in importance day by day and their usage becomes more widespread. Recently,

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computer-based image acquisition and processing techniques have been used commonly in various fields. Animal breeding is one of the sectors in which image analysis technologies are used.

In dairy cattle breeding, LW is important for monitoring milk yield, feed consumption, and live weight, because these terms reflect the efficiency of the farm and the current applications of feeding, feeding level, and the general situation of the cattle. The variations in the milk yield, the feed consumption, and live weight between 2 calvings of a cow can be observed in Figure 1. Being out of range for these properties negatively and significantly affects the resistance of the cows against diseases and their economical efficiency. Negative variations, especially in live weights, might indicate health problems, inappropriate environmental conditions, or feeding errors. For this reason, monitoring the LW of dairy cattle is important [1-3].

LW is determined by a weighing tool (scale) in cattle farms. Therefore, it might be necessary to construct a weighing place in farms or to place a weighing platform in the areas through which the cattle pass. There might be problems in the calibration or in the proper working of the weighing tools, which are exposed to environmental conditions. It might be necessary to employ a staff member for the weighing process. Although the aim is to weigh the animals with minimal stress, sometimes the cattle might be exposed to small injuries during the weighing. Therefore, farmers do not prefer to allocate space, staff, or financial resources to weighing tools.

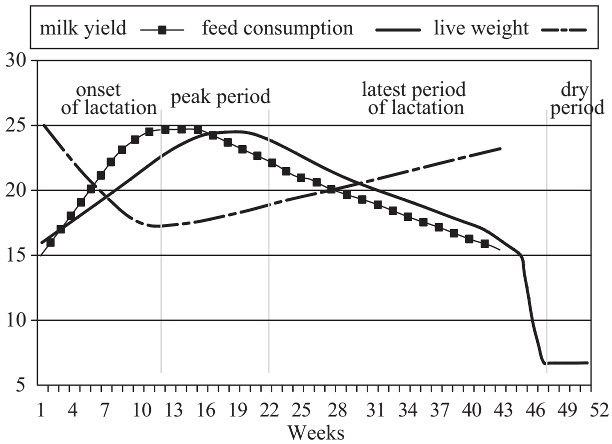

Figure 1. Period between 2 calvings of a Holstein cow.

Estimation of LWs by using body measurements has been done for a long time. While it is attempted to determine the LW both by weighing tools and by estimating body measurements by hand, the act of approaching the cows or forcing them into restricted areas puts them under stress and creates a danger for the person taking the measurements. The possibility of the measured sizes being wrong is also high due to the caution taken with the cows. For such unfavorable reasons, the farmers would rather not do LW monitoring or take body measurements, or would rather do this process more rarely than allocating a permanent place, staff, or budget for the weighing [3-7].

Computers are used in a wide variety of livestock fields. The usage of fuzzy logic (FL) is increasing rapidly with the use of computers. In experimental studies, some of the operating points of the system have been investigated. For this type of work, experts and special equipment are needed. It also requires much time and high costs. Fuzzy rule-based systems eliminate the limitations of the classical approaches by extracting the desired information using the input data. Recently, such systems have been widely used in areas that require computational techniques.

It would be possible to prevent all of these negative effects for both cows and staff during weighing, to minimize the errors, and to increase the sensitivity of the evaluations if this study is successful. In addition, the diagnosis and prevention of possible health problems resulting from feeding could be accelerated.

In the literature, there have been many successful applications in the field of animal husbandry using this method. Some of these are fuzzy and neuro-fuzzy approaches to modeling cattle grazing in pastures with low stocking rates in central Europe [8], mastitis detection in dairy cows by application of fuzzy logic [9,10], evaluation of modeling techniques for cattle heat stress prediction [11], dynamic weighing of dairy cows using a lumped parameter model of a cow's walk [12], the relationship of parameters of body measures and body weight using digital image analysis in preslaughter cattle [13], and walk-through weighing of pigs using machine vision and an artificial neural network [14].

In this study, the aim was to process digital images obtained from cows with the developed IA software and to determine the body measurements of the cows. A new approach was developed using a knowledge-based fuzzy expert system (FES) for estimating LW. Finally, LW was modeled through FES for prediction. FES predictions were compared with the experimental measurements.

2. Digital image analysis and photogrammetry

Computer vision is a science that allows information to be investigated by computers theoretically and algorithmically over an image or image sets. Digital image processing and analyzing methods supported by a computer have many advantages, like improving time efficiency, accuracy, and cost. The parameters related to objects are measured with digital IA (shape, length, area, angle, etc.). In raw digital images, measurements such as area and length can be made into pixels. In order to make these measurements in the metric system, the reference points on the image whose metric equivalents are known should be described by software (spatial calibration) [7,15-18].

Recently, there have been developments in image processing techniques and applications. One possibility for these visual applications can be obtained from photographs. The machine vision applications in electronic systems have been used increasingly in industrial areas. The contactless analysis of substances is preferred over other methods, because destructions or undesired negative variations might occur on a substance that is measured in contact.

Photogrammetric techniques, which are used for measuring objects from photographs, have been in use since the late 1800s. Digital close range photogrammetry is a technique for accurately measuring objects directly from photographs or digital images captured with a camera at close range. Multiple, overlapping images taken from different perspectives present measurements that can be used to create accurate 3D models of objects [18]. Using a digital camera with known characteristics (lens focal length, imager size, and number of pixels), there is a minimum of 2 images of an object. Unknown 3D points in the image can be determined with the aid of the indicated points of the same 3 objects and the known dimension in 2 images [17]. Photogrammetry is an efficient, rapid, and considerably safer method compared to classical methods. All surveyors can obtain precise measurements without physically accessing each measurement point. Digital photogrammetric methods have been successfully applied to projects in archaeology, architecture, automotive and aerospace engineering, accident reconstruction, and several other disciplines [19-23].

2.1. Calibration of the camera and direct linear transformation

Calibration of the camera is a mathematical calculation procedure for the parameters that should be known in order to bring metric properties to the camera. These parameters are the coordinates of the image center point, the focal length of the camera, the angles and coordinates of shooting, etc. The effect of distortion, which is one of the systematic errors on the image plane, is determined, and then the parameters are identified through calibration. These procedures are carried out in order to determine the inner geometry, optical characteristics, and angular position of the camera with respect to the 3D coordinate system. Calibration is defined as finding the relationship between the real value of the measured size and the result of the measuring device. Therefore, the coordinates of the 3D object points are known and the parameters of inner orientation are calculated [23-27,32].

Various calibration methods are present in the literature. These are linear, nonlinear, and multistage techniques. The linear method is faster than the others. The most commonly used method is direct linear transformation (DLT) [28]. The DLT method was suggested by Abdel-Aziz and Karara [29]. The reason for the widespread use of and preference for this method is that it is fast, has linear solutions, and does not have an approximate value problem [25,28].

A basic DLT equation is shown in Eq. (1) in matrix form.

$$\begin{bmatrix} x_1 & y_1 & z_1 & 1 & 0 & 0 & 0 & 0 & -u_1x_1 & -u_1y_1 & -u_1z_1 \\ 0 & 0 & 0 & 0 & x_1 & y_1 & z_1 & 1 & -v_1x_1 & -v_1y_1 & -v_1z_1 \\ & & & \vdots & & & & & & \vdots & \\ x_n & y_n & z_n & 1 & 0 & 0 & 0 & 0 & -u_nx_n & -u_ny_n & -u_nz_n \\ 0 & 0 & 0 & 0 & x_n & y_n & z_n & 1 & -v_nx_n & -v_ny_n & -v_nz_n \end{bmatrix} \begin{bmatrix} L_1 \\ L_2 \\ \vdots \\ L_{10} \\ L_{11} \end{bmatrix} = \begin{bmatrix} u_1 \\ v_1 \\ \vdots \\ u_n \\ v_n \end{bmatrix} \tag{1}$$

The relationship of transformation between the image coordinate system and the object coordinate system is mathematically stated in Eq. (2) [25,26]:

$$u - u_0 = -\frac{d}{\lambda_u}\frac{r_{11}(x-x_0)+r_{12}(y-y_0)+r_{13}(z-z_0)}{r_{31}(x-x_0)+r_{32}(y-y_0)+r_{33}(z-z_0)}$$

$$v - v_0 = -\frac{d}{\lambda_v}\frac{r_{21}(x-x_0)+r_{22}(y-y_0)+r_{23}(z-z_0)}{r_{31}(x-x_0)+r_{32}(y-y_0)+r_{33}(z-z_0)}, \tag{2}$$

where u_o and v_o are image points of the dot; u and v are image coordinates of the main point; r_{ij} represents the rotation matrix components; x, y, and z are matter coordinates of the point; λu and λv are unit transformation coefficients; d is the scale factor; and L_1, ..., L_{11} are camera calibration parameters. Rearranging Eq. (2), Eq. (3), the basic DLT, is found.

$$u = \frac{L_1x + L_2y + L_3z + L_4}{L_9x + L_{10}y + L_{11}z + 1} \qquad v = \frac{L_5x + L_6y + L_7z + L_8}{L_9x + L_{10}y + L_{11}z + 1} \tag{3}$$

The L_1, L_2, L_3,..., L_{11} coefficients in the equations are called DLT parameters. These reflect the relationship between the space reference plane and the image plane. Eq. (3) is a 3D DLT equation and does not include the optic distortion error of the camera lenses. If these errors are taken into consideration, the equation is arranged [29-31].

3. Block diagram of image acquisition and developed system

This study was carried out at Dairy Cattle Enterprise in the Çumra district of Konya province. A digital photo platform was set up at the farm, and pictures (n = 115) of Holstein cows were taken with Canon EOS 400D cameras. A photogrammetric technique for image analysis was used for determining the body measurements of the cows.

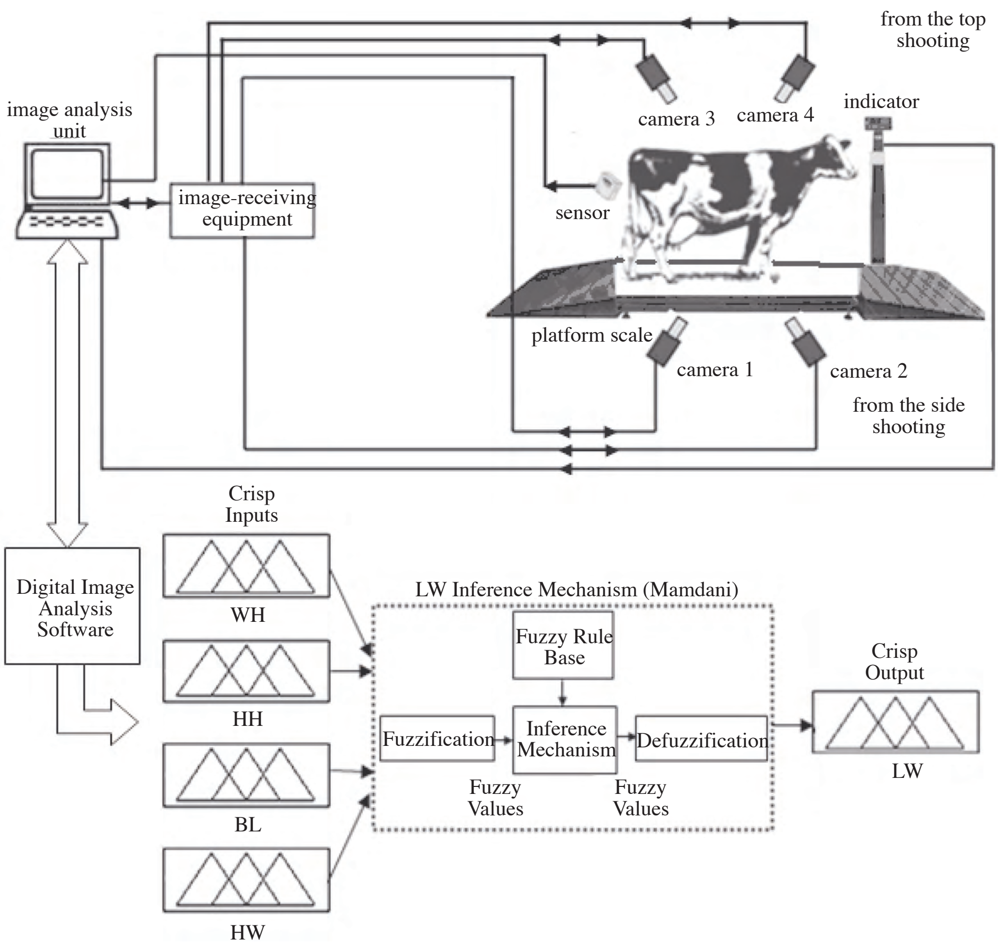

Figure 2. Block diagram of the image-taking unit and structure of FES for LW.

The setup in Figure 2 was designed and a photography area was built in which a lighting system was installed as suitable for stereoscopic shooting by hardware units. The reference points (coordinates were given for these points by geodesic methods and spatial coordinates) with known X, Y, and Z coordinates were marked on the places through which the cows would pass and be weighed before the digital image acquisition stage. Using this shooting position of the cameras, each mark on the milking shed was recorded on at least 2 images, and the 3D coordinates of the marks were determined. During the designing of the setup, the calibration process of the cameras placed on suitable points was performed since dimension calculation would be done. In this application, the relationship between the 2D image plane and the 3D world coordinate system was modeled and the parameters of the cameras were calculated. In this relationship model, the calibration parameters defining the cameras were calculated by using DLT method and camera calibration test area whose 3D coordinate values were known. A transformation was performed between the 2D image plane and the 3D spatial coordinate system with this procedure.

The WH, HH, BL, and HW of cows who would be photographed were first measured by laser meter (Bosch DLE 150 Connect Professional with Bluetooth), tape measure, folding ruler, and measuring stick. Their body measurements were then manually taken. While taking photos of the cows, the LW was determined by a digital weighing tool and the indicator data on display were saved to the computer (see Figure 2).

Photos of each animal from 2 different sidelong perspectives and from 2 different top perspectives were taken by synchronizing the Canon EOS 400D cameras with the help of the mechanism set up in the exit way of the milking shed. DSLR Remote Pro Multi-Camera v.1.2.1 software was used to support the Cannon cameras in order to take photos automatically and concurrently, i.e. synchronously, and it was integrated with visual IA software that was developed by the Delphi programming language. Moreover, a sensor reflecting from matter (Telemecanique Osiris XUK5APANL2 photoelectric sensor) was used, which automatically detected the passing of the animals. An electronic circuit was designed to perform the automatic photo shooting when an animal was detected. A program was written for a PIC16F877 microcontroller in this circuit. The synchronized photography was performed automatically by this program and the electronic circuit [36]. The photos were automatically taken and saved to computers with IA software and an electronic mechanism, using the Canon EOS 400D cameras. Thus, the pictures of animals, whose weights and manually measured body dimensions had been saved on the computer, were taken from side (2 cameras) and top (2 cameras) views by a total of 4 cameras. These images were evaluated in computers with IA software by using the determined reference coordinates and calculated body measurements of the cows. In other words, the XYZ coordinates were matched with the same point on the framework in the images taken. The images were analyzed with IA software developed by using the Delphi programming language. The manually measured values and the results of IA were compared. The FES was developed by using body dimensions, namely WH, HH, BL, and HW. This knowledge-based system was development with MATLAB software. Finally, LW was estimated by this FES.

3.1. Process of determining body measurements using the IA software

Calibration is the process of defining the relationship between the real value of the measured magnitude and the result given by the device that has measured that magnitude. In this application, the relationship between the 2D image plane and the 3D spatial coordinate system was modeled and the parameters of the cameras were calculated through the DLT method, and the measurements were performed by using the 3D coordinates corresponding to each pixel point. For this purpose, a studio shooting environment was established at the regular passageways of the animals, and the markings signifying the coordinates were fixed on those areas (Figure 3). A large number of marked points were determined, considering all of the alternatives. These points were tested by using the IA software that was developed for the study; the 3D coordinates providing the most correct results were selected and used in the software. For evaluating the photos of animals taken from sidelong perspectives (Figure 4), 9 point were found to be adequate, and 14 points were found to be adequate for evaluating the images of animals taken from top perspectives.

In the IA process, the pixels (x,y) in the images that corresponded to the 3D points determined on the right and left stereo images were selected by using the mouse. Afterwards, the 3D object coordinates that corresponded to these pixels were entered separately for each image (see Figure 4). The basic first matrix, A in Eq. (1), used for the camera calibration process was created according to the DLT method. Since 9 points were selected, the created A matrix was composed of 11 columns and 18 rows. The second matrix, the L matrix, was formed with the 9 pixels (x,y) marked on the right and left images according to the DLT model. The L matrix consisted of 1 column and 18 rows. The image center point, focal length of the camera, shooting coordinates, rotation angles, and distortion parameters were found through matrix operations using DLT. These camera calibration variables were calculated for both right and left images using the IA software, and the results obtained through the calculations were recorded on the computer for further analysis.

Figure 3. 3D reference coordinate points fixed on the area created for the process of taking photos from sidelong perspectives.

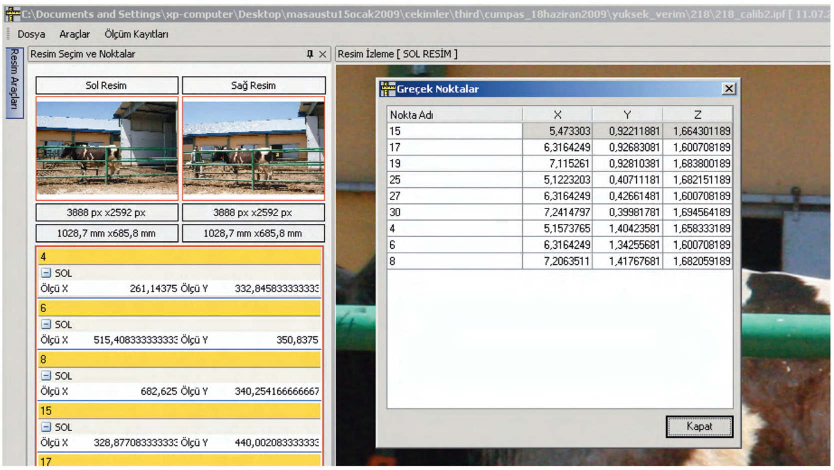

Figure 4. Entering the 3D reference points used in evaluating the photographs taken from sideways (from the right and left stereo, and synchronized) into IA software.

The next stage in the operation of the IA software was the process of finding the 3D coordinates of a desired pixel point on the image. It is possible to obtain the space coordinates directly from the image coordinates through DLT equations. An (XYZ) will be calculated corresponding to each pixel point (x,y) on images marked using the mouse. The procedure was implemented by using the pixel points marked on the right (x_1,y_1) and left (x_2,y_2) images and the calibration variables obtained by using these points. In this way, the transformation process, or in other words the transformation from 2D (x,y) pixels to 3D (XYZ) object space coordinates, was realized. That is, the XYZ space coordinate values corresponding to a pixel point selected on the image were calculated. When the XYZ values of the second pixel point on the image were found, the distance between the 2 pixel points could be calculated with Euclid's relation. WH, HH, BL, and HW were calculated by analyzing the taken images in the IA software.

4. Fuzzy rule-based modeling for predicting LW

The fuzzy model is a knowledge-based model with linguistic rules. Human experts frequently use natural language for describing a system or process that has to be modeled. These fuzzy sets, which are defined for all input and output variables and the set of rules, form the knowledge base (fuzzy rule base) of the model. Fuzzy logic provides the means to process this knowledge and compute output values for given input data. The major problem of this approach is finding a suitable set of linguistic rules that describe the system to be modeled. They can be formulated directly by an expert, but it is a difficult procedure because the expert's knowledge might be too complex to be written as a limited set of rules. The set of rules should be complete and should provide an answer for every input value. The union of fuzzy sets defined for the input variables should 'cover' the value space of these variables. The number of the rules should be increased unless this condition is satisfied. If this is not possible, the support of fuzzy sets should be extended. It should be noted here once again that the formulation of the linguistic rules and the definition of fuzzy sets are of a subjective nature [8,33].

The fuzzy subset theory was introduced by Zadeh in 1965 as an extension of the set theory by the replacement of the characteristic function of a set by a membership function whose values range from 0 to 1 [33,34]. Unconventional modeling methods better employ uncertain or imprecise data and vague knowledge about model components. The 3 steps of a fuzzy logic system are fuzzification, fuzzy inference, and defuzzification [9,33].

Fuzzification is the transformation of numerical variables into linguistic variables and the corresponding allocation of the grade of membership (a scalar between 0 and 1) to the diverse membership functions [10]. The linguistic combination of the traits is carried out in the fuzzy inference. The rules used result from human knowledge and have the form of: if condition, then conclusion. The degree to which each part of the condition has been satisfied for each rule is known by the corresponding grades of membership [9]. Defuzzification is the transformation of the fuzzy values into an output value and the comparison with the real output data in order to evaluate the performance of the model. Through the calculation of the center of gravity of these areas, the fuzzy values are transformed back in order to resolve a single output value from the set [9,10,33].

The centroid method is used for defuzzification. The centroid of the composed shape is computed by:

$$Z = \frac{\mu_c(z) z \delta z}{\mu_c(z) \delta z}, \tag{4}$$

where z is the consequent variable and $\mu_c(z)$is the function of the composed shape [11,34].

FES, which is a knowledge-based model for the estimation of the LW obtained from body measurements by using IA, was used. The FES was developed by MATLAB software. We can set up prototype triangular and trapezoid membership functions for the fuzzy variables as inputs and outputs. The model proposed in this study is a 4-input, 1-output model. The general structure of the developed FES is shown in Figure 2. The fuzzy membership functions for each of the 4 input variables and the 1 output variable were determined. Input variables, namely WH, HH, BL, and HW, and output variable LW are shown in Figure 5. The FES was designed with the help of a human expert working as a professor in the Department of Zootechnics of the Faculty of Veterinary Medicine of Selçuk University.

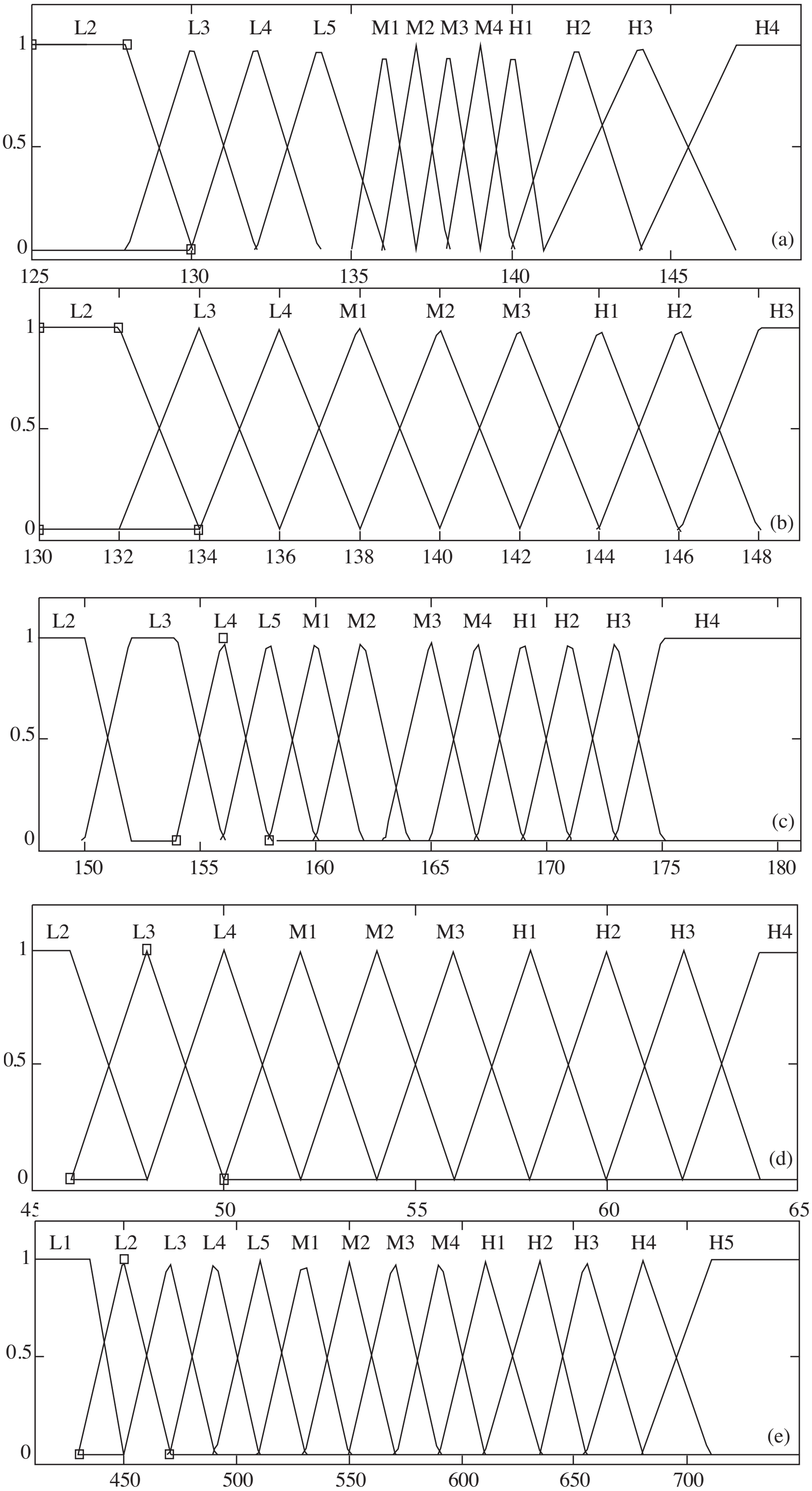

Figure 5. The fuzzy membership function structures for 4 input variables, WH (a), HH (b), BL (c), HW (d), and 1 output variable, LW (e).

Input and output crisp numerical data were fuzzified and converted into linguistic variables, such as extreme low (L1), lowest (L2), lower (L3), low (L4), almost low (L5), under medium (M1), medium (M2), over medium (M3), upper medium (M4), almost high (H1), high (H2), higher (H3), highest (H4), and extreme high (H5), as shown in the Table. The range of the values of these linguistic expressions could be determined and expressed as formulas by meeting with a human expert.

Table. Some of the rule sets of structure for the Mamdani fuzzy inference mechanism.

Rule No.		WH		HH		BL		HW		LW
1	If	L2	and	L3	and	L3	and	L2	then	L1
2	If	L2	and	M2	and	L3	and	L2	then	L1
3	If	L2	and	L2	and	L3	and	L2	then	L2
4	If	L3	and	L2	and	L3	and	L2	then	L2
....										
50	If	M1	and	M2	and	M4	and	M1	then	M3
51	If	M1	and	M2	and	M3	and	M1	then	M4
52	If	M2	and	M1	and	M1	and	M1	then	M2
53	If	M2	and	M2	and	M2	and	M3	then	M3
....										
108	If	H3	and	H2	and	H3	and	H3	then	H5
109	If	H3	and	H3	and	H3	and	H4	then	H5
110	If	H3	and	H2	and	H4	and	H4	then	H5
111	If	H4	and	H3	and	M3	and	H1	then	H1

As can be seen from the Table, the system knowledge base was constituted from 111 fuzzy rules. For example, rule 4 from the Table can be explained as follows. If WH is lower (L3) and HH is lowest (L2), and BL is lower (L3) and HW is lowest (L2), then LW is lowest (L2). The structure of the developed FES consisting of fuzzification, a knowledge base (fuzzy rule base), a fuzzy inference engine, and defuzzification is shown in Figure 2.

When the input data are entered to the system, one or more rule can be fired. In this case, the inference mechanism determines what the output is going to be. The validity degrees (α) for each rule are calculated according to the Mamdani max-min rule. The Mamdani approach was used as the fuzzy inference mechanism because of being simple and easy to use. It was used to determine the degree of truth for each rule when the Mamdani max-min inference was applied. For each rule, the degree of truth was calculated and these degrees of truth were used to calculate the LW. At the defuzzification process, the exact expression was obtained with the centroid method according to a validity degree by using the formula given in Eq. (4).

For example, the output value obtained from the developed FES, LW, which was found to be 450 kg with respect to input values WH = 129 cm, HH = 132 cm, BL = 152 cm, and HW = 47 cm, is shown in Figure 6. A total of 2 rules were fired, called rule 3 and rule 4. The degree of truth was computed according to the max-min inference mechanism. At the defuzzification process, the exact expression was obtained with the centroid method from Eq. (4) according to a validity degree.

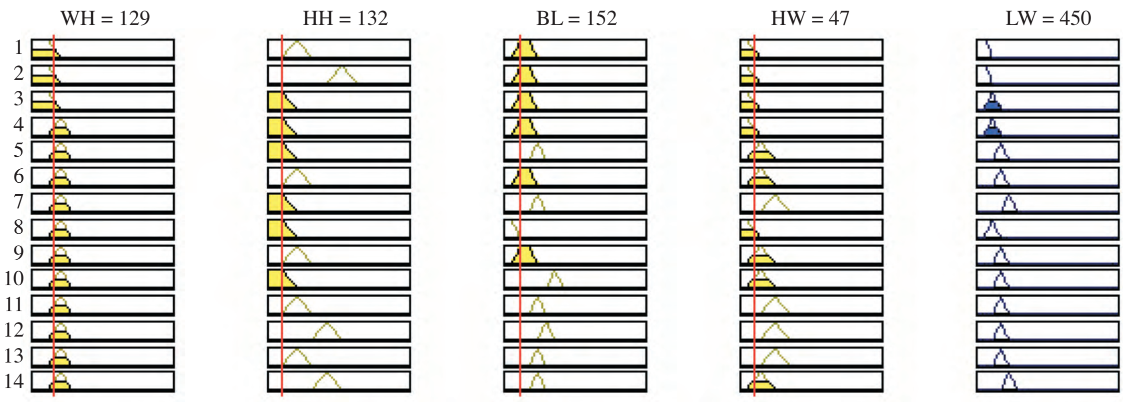

Figure 6. An example for LW prediction interactive interface generated by software with centroid defuzzification.

5. Results and discussion

In this study, WH, HH, BL, and HW values of animals were both manually measured and obtained by evaluation with IA software. The accuracy rates from Eq. (5), between manually measured body measurements and those obtained as a result of the IA procedure, were found to be 97.72% for WH, 98.00% for HH, 97.89% for BL, and 95.25% for HW. Furthermore, the root mean square error (RMSE) from Eq. (6) was calculated as 3.99 for WH, 3.52 for HH, 4.43 for BL, and 3.27 for HW. When these rates are taken into consideration, it can be observed that the manually measured WH, HH, BL, and HW values were very close to and in accordance with those obtained as the result of the IA procedure.

The estimated performance was calculated by using Eqs. (5) and (6) and was assessed with mean relative percentage error (MRE), RMSE, and correlation coefficient (r) values. The results of LW estimated by FES were compared with the values obtained by the weighing, and their accuracy was tested as a percentage. MRE and RMSE were calculated [35].

$$MRE(\%) = \frac{1}{n}\sum_{i=1}^{n}\left[100 * \frac{|d_i - O_i|}{d_i}\right] \tag{5}$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(d_i - O_i)^2} \tag{6}$$

Here, d_i represents manual values, O_i is the value predicted by FES, and n is the output data number.

It was also shown that the FES estimates better results by using the MRE evaluation. The mean relative percentage accuracy was 98.93% for FES. It was observed that the estimated LW values were close to the real LWs and there was a strong concordance between them. As can be understood from this rate, the LW of cows can be estimated by using FES with a 1.07% error.

In this study, the LW of cows was estimated with FES methods by using IA data. The values measured with the weighing tool (experimentally obtained by scales) and estimated FES values were graphically compared. In Figure 7, it can be seen that the data obtained from the developed system and the experimental data were fitting and close.

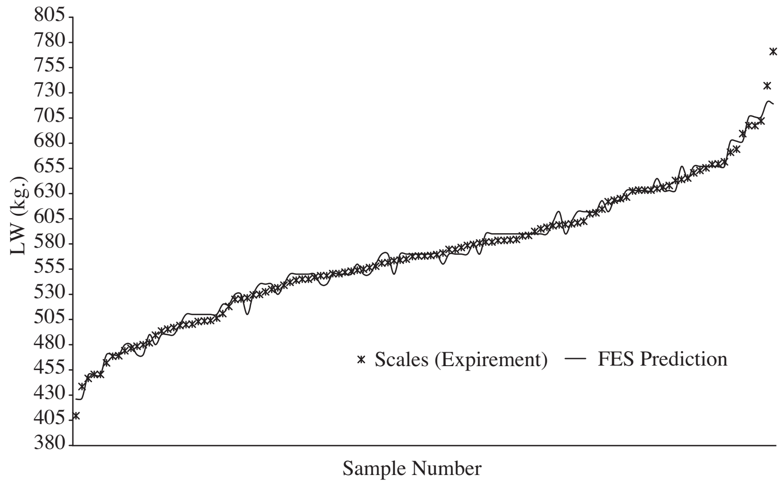

Figure 7. Comparative graph of experimental (scales) and FES live weight data.

The realized system results and the values measured by the weighing tool were evaluated by using regression analysis. The graph of the regression between the estimated FES values and the values measured by the weighing tool, shown in Figure 8, indicates that the correlation coefficient was 0.99. As the correlation coefficients get closer to 1, estimation accuracy increases. In the case presented in this study, the correlation coefficients obtained were very close to 1, which indicates a perfect match between FES estimation values and experimental measurement values. There were no meaningful differences between the experimental results and FES results.

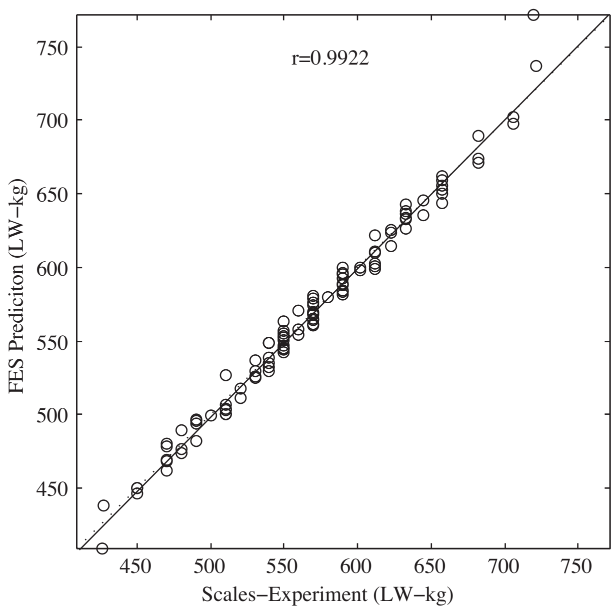

Figure 8. The relationship between scales (experiment) and FES prediction values of live weight.

The usage of FES modeling may be highly recommended to predict LW instead of time-consuming experimental studies.

6. Conclusion

The aim of this study was to show the possibility of using FES for predicting LW. Results showed that the FES can be used as an alternative and new method for LW estimation.

In this study, it was shown that body measurements of Holstein cows can be obtained by using IA operations. Computer IA methods for evaluating the morphology of Holstein cows and for estimating LW by means of FES appear to be very reliable. This analysis of body measurements of animals is viable, quick, effective, and very practical. In addition, this approach could be used efficiently as a directly computerized and more precise recording system in comparison with metric measurements.

The cost, difficulty, staff requirements, danger, and stress problems during manual measurement and weighing of animals would be solved by using the digital IA method and fuzzy rule-based predictions. It would be a reasonable solution to evaluate the cows with this system by taking their digital images from various directions and different angles at a certain distance in a computer-aided environment like a studio, where the computers are set up along the paths where the cows pass, at the entrance and exit of milking parlors or in front of the automatic feeding units, in order to prevent the negative outcomes that might occur for both cows and staff during weighing.

Experimental data measured with the weighing scale were compared with the results obtained from the FES, and all data were statistically analyzed. When the analysis was assessed, the LWs obtained from the FES were very close to the experimental results obtained from the weighing scale. Therefore, it was seen that the FES might be used safely. FES as an alternative method can be used for estimating LW. As seen from the results, the FES modeling has a sufficient accuracy rate for the estimation of LW.

FES is able to eliminate the difficulties in the experimental studies, i.e. economic loss, time loss, measurement errors resulting from the sensitivity of measuring tools, and loss of sensitivity. The main advantage is the reduction of laboratory costs and processing time by eliminating laboratory-intensive tasks. This approach is a simple way (mathematical functions are easy to implement) to integrate operator reasoning whenever the operator is involved in the measurements. This system works effectively and rapidly.

LW observations, especially in big herds, will be carried out more frequently and in a more sensitive and objective way. Decreasing the possibility of errors and increasing the sensitivity of evaluations will increase the efficiency and provide prevention and diagnosis of possible health problems resulting from feeding programs. Moreover, when the difficulties in the monitoring of all cows in large-sized dairy cattle farms are taken into consideration, it will be better understood that this developed image analysis system will provide ease of usage, contribution to herd management, and gains in time and economy.

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