Andrzej PRZYBYLAK*, **Piotr ŚLÓSARZ****, **Piotr BONIECKI***, **Dariusz LISIAK*****,
Marek STANISZ**, **Agnieszka LUDWICZAK****
* Institute of Agricultural Engineering, Poznań University of Life Sciences
** Department of Small Mammalians Breeding and Animal Origin Materials Poznań University of Life Sciences
*** Division of Meat And Fat Technology, Institute of Agricultural And Food Biotechnology

NONINVASIVE ESTIMATION OF MARBLING IN LAMB'S CARCASSES

Summary

An important, and not yet solved problem in meat industry is the issue of estimating the intramuscular fat level content in the carcass. Solution of the problem of identification of quantity of the intramuscular fat, on the basis of information in ultrasound images taken on lamb's carcasses or even living animal, is of essential utilitarian importance. The amount of intramuscular fat (known as marbling) has significant impact on market value and meat's culinary usefulness. Previously used methods for marbling classification in carcasses based on an analysis of animal's age, weight and gender, or had invasive nature. These methods were estimated as unreliable and inefficient. There have been noticed growing explorers' interest in drawing conclusions based on information of data coded in a graphic form. The neuronal identification of pictorial data, with special emphasis on both quantitative and qualitative analysis, is more frequently utilized to gain and deepen the empirical data knowledge. Extraction and then classification of selected picture features, such as color or surface structure, enables one to create computer tools in order to identify these objects presented as, for example, digital pictures. This paper presents an attempt to create noninvasive method to classify marbling, based on ultrasound images, computer image analysis and artificial neural networks.

NIEINWAZYJNA OCENA MARMURKOWATOŚCI TUSZ JAGNIĘCYCH

Streszczenie

Ważnym, i dotychczas nierozwiązanym problemem w branży mięsnej jest ocena poziomu zawartości tłuszczu śródmięśniowego w tuszy zwierzęcej. Rozwiązanie problemu identyfikacji ilości tłuszczu śródmięśniowego na podstawie informacji pozyskanej z obrazów USG tusz zwierzęcych, a także żywych zwierząt, ma istotne znaczenie utylitarne. Ilość tłuszczu śródmięśniowego (tzw. marmurkowatość) ma znaczny wpływ na wartość rynkową i przydatność kulinarną mięsa. Stosowane dotychczas metody oceny otłuszczenia zwierząt bazują na analizie ich wieku, masy ciała oraz płci lub maja charakter inwazyjny. Metody te są zawodne oraz mało efektywne. Widoczny jest wzrost zainteresowania wyciąganiem wniosków bazując na danych zakodowanych w formie graficznej. Neuronowa analiza obrazu, ze szczególnym uwzględnieniem analiz ilościowych i jakościowych, jest coraz częściej wykorzystywana analizy danych empirycznych. Wydobycie a następnie klasyfikacja wybranych cech obrazu, takich jak kolor, kształt czy tekstura, możliwa jest dzięki wykorzystaniu systemów informatycznych analizujących i przetwarzających obrazy cyfrowe. W artykule przedstawiono próbę wytworzenia nieinwazyjnej metody klasyfikacji marmurkowatości, z wykorzystaniem zdjęć USG, komputerowej analizy obrazu oraz sztucznych sieci neuronowych.

Introduction

Quality assurance is one of the most important goals of the meat industry. The ability to meet consumer expectations by providing quality products and maintaining the consistency of products is the basis for success in today's highly competitive market. The animal's fat content in the moment of slaughter has a crucial influence on its market value. Modern USG appliances allow to obtain images of tissue's cross-section and this may lead to precise measurement of, for instance, the intramuscular fat level content. In addition, the most important advantage of using the ultrasound is its noninvasive character. The reflection of the quantity and layout of intramuscular fat on muscle transverse cross-section is defined by marbling. Moderate marbling, positioned appropriate is feature of quality and it is desirable especially in cattle's beef estimation process. Excessive marbling can limit or even completely eliminate its processing aptitude [5].

Ultrasound is a noninvasive diagnostic imaging technique used to effective for imaging soft tissues of the body. Ultrasound works through the generation of harmless sound waves from transducers into living systems. As the sound waves propagate through tissue, they are reflected back and picked up by the transducer, and can then be translated into 2D and 3D images. The performance of ultrasound imaging is often perceived as to be linked with the experience and skills of the operator using a hand-held probe (called a transducer) that is placed directly on and moved over the examined tissue) [7].

Image is increasingly becoming a source of information used in many practical applications. Acquiring images of objects is not currently a problem. To effectively use the data contained in the images (often impossible to detect by man), they must be adequately prepare for the analysis process. Before image can be analyzed by a digital device such as a PC, it must be converted from analog to digital form.

Digital image is represented as a two dimensional table of numbers and its fundamental elements are pixels. The process of displaying an image creates a graphical representation of this matrix, where the pixel values are assigned to a particular color or grey value. Image texture has been widely used in computer vision for segmentation and feature extraction. One way to bring the texture information into analysis is to consider not only the distribution of intensities but also the position of the pixels [1].

Both processes: image processing and analysis are used to create a data set, known as training set (representative set of features extracted from images) for artificial neural network simulator. The information contained in training set have a direct impact on the quality of the generated neural models.

Artificial neural network is mathematical model or computational model that tries to simulate the structure and/or functional aspects of biological neural networks. In most cases an neural network is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase. Modern neural networks are non-linear statistical data modeling tools. They are usually used to model complex relationships between inputs and outputs or to find patterns in data.

The utilization of artificial neural networks for image analysis requires the proper generated training sets. In the case of obtaining information from digital images is needed to convert them to form accepted by the artificial neural network simulator. For the correct model's functioning it is crucial that the training set contained the representative features.

The aim of the study is to create neural classifier to estimate the grade of intramuscular fat level based on ultrasound images. Early studies have shown that image analysis technology has great potential to improve the current human grader based meat quality operation.

Material and methods

The data were collected from 45 slaughter lambs. Right after slaughter, carcasses's longissimus dorsi muscle cross-section (at 3 locations: behind 5^{th} and 13^{th} rib and 3^{rd} lumbar vertebrae) and two leg muscles cross-sections (*m. biceps femoris, m. semimembranous*) were monitored using a Hitachi EUB-405B with a linear 5.0 MHz probe. Ultrasound images were stored in the BMP format (8bpp color palette).

After slaughter and twenty four carcass-cooling period, samples of the muscles were collected at the site of the ultrasound examinations and marbling class was estimated by using the class pattern sheet for cattle. Based on the 5 class pattern, lamb's marbling has been attributed to 10 new classes (each class from original pattern was divided in half). From each carcass 5 cross-section were analyzed, with 3 USG imager per each, that gave total number of 675 samples to analyze.

Enhancement algorithms were used to reduce image noise and increase contrast of structures of interest and to provide a clearer image for preprocessing stage for automated analysis.

All the operation in processing stage were executed by using the freeware software InfanView v. 4.25.

Image analysis and the creation of representative set of features was possible by using the copyright software "IMG.2.CSV".

An important part of research was to estimate the influence of size of input vector on the network's response. Number of variables in the data set determine the number of learning cases in training set. For purpose of data extraction two selection frame were used: 100×100 pixels and 200×100 pixels.

The both type of selection frames were applied on each image. The selection was copied to another panel and need to be accepted by operator. Next stage was to calculate the average values for each 10×10 block from selected part, then code these values using coding pattern (fig. 2) introduced by Nowakowski. That scheme proved to be suitable for the purpose of image analysis [2].

In this case, all 3 values (R,G,B) were equal, since the conversion to grayscale format. What is worth mentioning, values coded by this pattern are easy to decode to original RGB form.

Calculated and coded average values, with added database signature (filename) and network's output value (corresponding marbling class) were stored in CSV file. Depending on the case (used selection frame), training set contained 100 or 200 input variables.

Generated set of teaching vectors were used in neural network simulator package "STATISTICA v. 7.1". Teaching set was divided in the default proportion 2:1:1. Following algorithms were used in the study process:

- Back Propagation algorithm (BP) - it is an elementary algorithm of supervised study of the one-way multilayer neural networks. It provides changing signal significance input of each neuron of every layer.
- Conjugate Gradient algorithm (CG) - it is an advanced method of studying about multilayer perceptrons.

Fig. 1. Example of using the 200x100 frame to create a training set

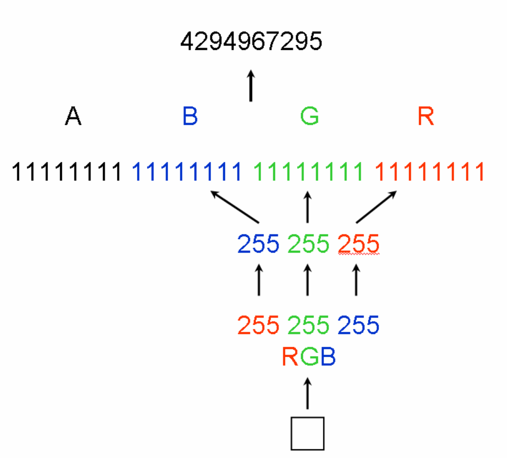
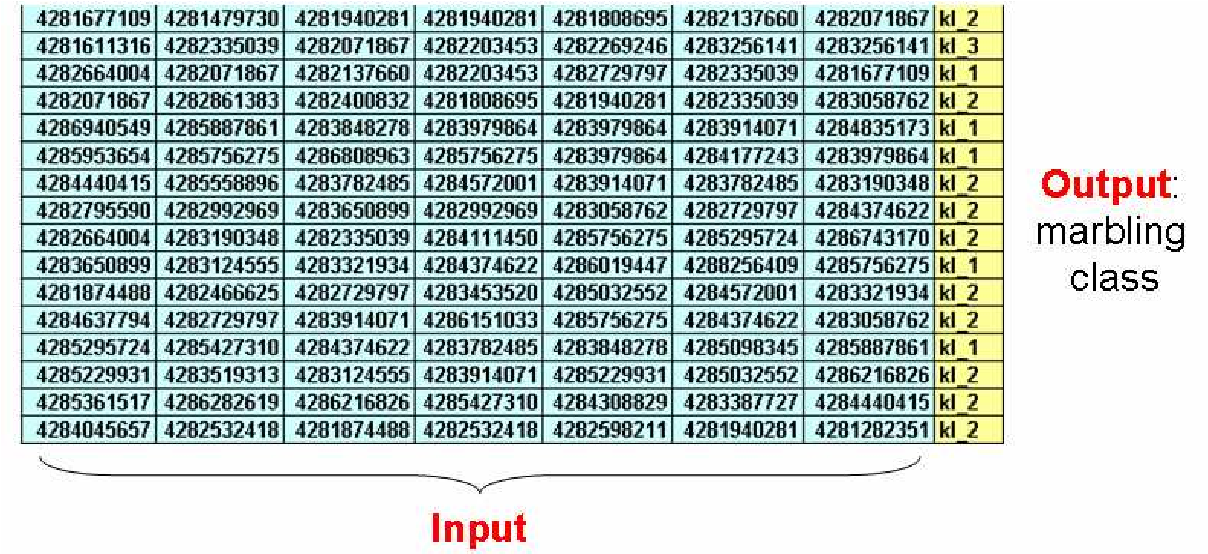


Fig. 2. Variables coding scheme



4281677109	4281479730	4281940281	4281940281	4281808695	4282137660	4282071867	kl_2
4281611316	4282335039	4282071867	4282203453	4282269246	4283256141	4283256141	kl_3
4282664004	4282071867	4282137660	4282203453	4282729797	4282335039	4281677109	kl_1
4282071867	4282861383	4282400832	4281808695	4281940281	4282335039	4283058762	kl_2
4286940549	4285887861	4283848278	4283979864	4283979864	4283914071	4284835173	kl_1
4285953654	4285756275	4286808963	4285756275	4283979864	4284177243	4283979864	kl_1
4284440415	4285558896	4283782485	4284572001	4283914071	4283782485	4283190348	kl_2
4282795590	4282992969	4283650899	4282992969	4283058762	4282729797	4284374622	kl_2
4282664004	4283190348	4282335039	4284111450	4285756275	4285295724	4286743170	kl_2
4283650899	4283124555	4283321934	4284374622	4286019447	4288256409	4285756275	kl_1
4281874488	4282466625	4282729797	4283453520	4285032552	4284572001	4283321934	kl_2
4284637794	4282729797	4283914071	4286151033	4285756275	4284374622	4283058762	kl_2
4285295724	4285427310	4284374622	4283782485	4283848278	4285098345	4285887861	kl_1
4285229931	4283519313	4283124555	4283914071	4285229931	4285032552	4286216826	kl_2
4285361517	4286282619	4286216826	4285427310	4284308829	4283387727	4284440415	kl_2
4284045657	4282532418	4281874488	4282532418	4282598211	4281940281	4281282351	kl_2

Fig. 3. Fragment of training set

Results

Several network topology was tested and MLP (Multilayer Perceptron) turned to be optimal network model for described problem for both 100 and 200 input values (table 1).

Neural network based on 200 input values produced the highest classification ratio. Optimal network consist of three layers and have 29 hidden neurons (fig. 4). Network's classification ratio was estimated at 0,68 (where 1 is perfect).

Networks based on 100 input values from 100×100 pixel frame selection had a significantly lower accuracy (rated at 0,37) than the networks described above.

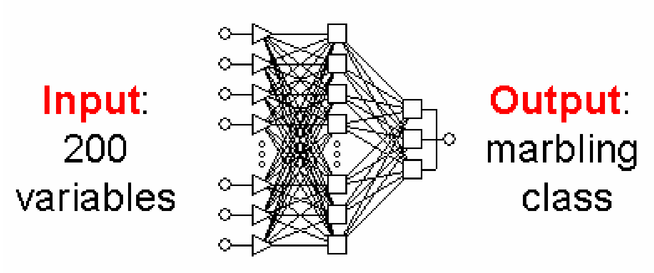


Fig. 4. Optimal neural network scheme (MLP 200:29:1)

Table 1. Results for neural networks based on 200×100 selection frame

	Type	Inputs	Hidden	T Error	V Error	Te Error	T Perf	V Perf	Te Perf	Training
1	Linear	200	-	6,10E-15	1,450417	1,56604	1	0,5	0,4404762	PI
2	Linear	200	-	9,97E-15	1,26361	1,341245	1	0,4761905	0,3928571	PI
3	Linear	200	-	1,04E-14	1,183361	1,24443	1	0,4404762	0,3452381	PI
4	RBF	200	1	0,7726231	0,664882	0,7464234	0,2781065	0,4642857	0,3452381	KM,KN,PI
5	RBF	200	2	0,4014272	0,450175	0,4024658	0,6568047	0,4761905	0,6309524	KM,KN,PI
6	RBF	200	1	0,4014139	0,450078	0,4017431	0,6568047	0,4761905	0,6309524	KM,KN,PI
7	MLP	200	1	0,4034078	0,449101	0,4026081	0,6568047	0,4761905	0,6309524	BP23b
8	MLP	200	30	0,415795	0,419231	0,4093956	0,6035503	0,5714286	0,5714286	BP35b
9	MLP	200	35	0,3567489	0,412489	0,4202777	0,7810651	0,6428571	0,5952381	BP36b
10	MLP	200	25	0,1996048	0,391428	0,3926694	0,9526627	0,6785714	0,6547619	BP50,CG47b

Fig. 5. Visualization of both selection frames (100×100 and 200×100 pixels)

These results seems to be right, since the 100×100 selection frame described approx half of visible muscle's area, where 200×100 selection frame covers almost entire muscle cross-section area (fig. 5).

Conclusion

The usefulness of neural networks of the MLP type for the classification of marbling has been demonstrated.
Conducted examinations showed that a structure of the input had the significant influence on the quality of the classification.

The optimum selection of variables and teaching numbers cases significant affect the quality of the process of teaching of neural network of the MLP type.

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