APPLICATION OF VIA AND NEURAL NETWORKS IN OBJECTIVE BEEF CLASSIFICATION AND PREDICTION OF CARCASS COMPOSITION

MADSEN N.T. and THODBERG H.H.

Danish Meat Research Institute, Roskilde, Denmark

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SUMMARY

Visual classification of conformation and fatness has traditionally been carried out over a number of years within the Danish classification system in accordance with the EU EUROP-system. Carcasses are graded in classes from 1 to 15 for conformation and from 1 to 5 for fatness.

Visual assessment is difficult to conduct consistently over time and uniformly between classifiers under various conditions. Development of an objective classification system has been a major requirement from beef producers. The Danish Beef Classification Center (BCC) was developed with the aim to predict composition as well as the EUROP grades. However, composition could be calculated with similar accuracy from weight and visual EUROP conformation and fatness. A validating experiment in 1993 resulted in only marginally better accuracy for composition using the BCC. However, application of neural networks for interpretation of the video image produced a clear advantage of the BBC for carcass composition. Furthermore, EUROP conformation was predicted much better.

2810 carcassses were measured in the BCC and visually classified in a commercial plant, and 230 carcasses (young bulls, cows and steers) were cut according to a defined commercial standard. A back propagation neural network was trained and cross validated. 99.9% of the carcasses could be classified despite minor slaughter damages. Saleable yield, fat trim and bone had a standard deviation of 2.33%, 2.62%, 2.33% and were predicted using neural networks with a R^2 of 75%, 86%, 82% and a standard error of prediction (SEP) of 1.23%, 1.04 and 1.06, respectively. Improvement in SEP over visual classification was 7%, 9%, and 9%, respectively.

EUROP conformation and fatness were predicted with R^2 of 90%, 63%, and SEP of 0.74, 0.52, respectively. The number of carcasses deviating more than 1 conformation class was reduced from 9.4% to 3.7% and from 0.6% to 0.3% for fatness class, using neural networks compared to traditional algorithms. This level of accuracy is similar to the agreement between very experienced classifiers.

Introduction

In Denmark bovine carcassses are classified according to EU and Danish regulations for conformation and fatness. For a long time, however, there has been a desire for a more objectively based classification system, in order to obtain the best possible basis for carcass quality payment, and to ensure a good correlation with yield and value of saleable meat. A Danish system, the BCC, for semi objectively based classification of EUROP conformation and fatness and also carcass composition was described by Sørensen et al. (1988) and Ovesen (1991). In 1991 the development of the BCC was finished and the classification performance level was as reported by Klastrup (1990). Due to structural changes in the industry no decision was made on further installation of the BCC. In 1993, however, continued press for objective classification led to a validating experiment which included both EUROP classification and cutting of carcasses. The main objective was to confirm whether carcass composition could be calculated from the BCC with similar accuracy as from weight and visual EUROP conformation and fatness, as reported by Sørensen et al. (1988). However, only marginally better accuracy for composition was achieved when using the BCC (Madsen, 1993). In order to improve performance for both composition and EUROP classes a new approach was applied to extract more information from the video image and neural networks used to develop classification algorithms. The significantly improved results of these methods are described as follows.

Materials

The BCC installed on-line in a commercial slaughterhouse (Kolding) was used to measure and sample data from 2810 carcasses distributed on 32 days during a period from November 1992 to July 1993. Data are assumed to be representative for carcasses at the plant with regard to normal variation in season, weight, category, EUROP-class and breeds.

Carcasses selected for cutting consisted of 28 steers and 99 young bulls produced for other experimental purposes under the EGTVED research program. The 103 cows were selected especially for this project and directed on dual purpose dairy breeds mainly. Therefore, the full variation in carcass composition for the Danish population is by no means covered by data. However, data are considered to reflect the variation sufficiently well to make conclusive analysis on classification performance. Before practical application some supplementary carcasses should be included.

Methods

All carcasses were measured at the end of the slaughterline in the BCC. The BCC functions and methods are described by Sørensen et al. (1988), Madsen et al. (1993) and EU-Patent (1993). The video images were stored on optical discs for control and further analysis. Visual EUROP classification was performed by the slaughterhouse classifier within 1 hour of weighing of the carcass according to Danish regulations (DBCB, 1991). 230 carcasses were selected for commercial cutting the following day. Cuts, fat trim and bones were weighed according to an Institute standard that closely reflects standards used in the industry. The standard was identical to the one used in the first BCC cutting trial by Sørensen et al. (1988). A new method for image analysis was developed. Rather than identifying few important fixpoints and calculating widths, lenghts and curvature used as inputs for the classification algorithms, the approach was changed to reflect the presumed visual classifiers method, where the impression of the total carcass image is converted into a classification result.

Thus the full carcass contour and image is used in the calculation. This increases the number of input data for processing by a factor of 100, which improves robustness of the result to minor slaughter damages, or to carcass or image irregularities. Image data are first weighted according to importance and then preprocessed by principal component analysis (PCA). The principal components are then used as input data to train a neural network. A network was constructed with 17 input channels and 4 hidden neurons. 13 input channels were assigned to image components, and the remaining to weight and probe measurements of meat and fat thicknesses.

PCA was also succesfully used to identify suspect carcasses with major slaughter damages or other abnormalities.

For validation of EUROP class prediction, 2/3 of the 2810 carcasses were used to train the network and then tested on the remaining 1/3 of data. Difference in SEP for EUROP conformation between training and testset was in the order of only 0.03, so all SEP values in this paper refer to calculations on the full dataset.

In previous BCC models operator entry of category (sex, age) was needed as category was used as input variable. With improved use of the image information this is no longer necessary.

For composition the data were limited to 230 carcasses. Hence the neural network outputs were used as input in a linear model.

Results

Using more of the image information and the neural network approach implied that very few carcasses were discarded as unclassifiable due to slaughter damage etc.. It is estimated that only aproximately 0.1% cannot be classified in the BCC (Thodberg & Madsen, 1993).

EUROP classification

Classification performance for EUROP conformation was improved considerably with the new method. The relation between classifier and BCC is shown in figure 1. Comparison of the relationship between visual classification performed by inspector or slaughterhouse classifier is shown from a previous test in 1990, figure 2.

Figure 1. **Relation between EUROP conformation determined by slaughterhouse classifier or BCC using neural networks on 2810 carcasses in 1993.**

Figure 2. **Relation between EUROP conformation determined by classification inspector or slaughterhouse classifier on 2481 carcasses in 1990.**

Around 90% of the variation in conformation is described with the new method compared to 80% in previous BCC algorithms. SEP values and percentage of carcasses deviating more than 1 class confirm the improvement of the new method, figure 3.

Figure 3. **SEP, and % deviating more than 1 class for EUROP classification using either the old model or the neural network in the BCC, for comparison inspector - classifier agreement is shown from a 1990 experiment.**

The EUROP classification performance of the BCC is considered equivalent to or better than the relation between independent visual grading by experienced classifiers (1990-trial). A smaller experiment showed further potential for improvement by a subdivision of the fatness scale as for conformation.

Despite that SEP values for the inspector-classifier agreement are slightly lower compared to the neural network model it is still considered as good because some of the reference values are expected to be "off calibration" due to natural human error, thereby inflicting a false error on the BCC result. A better comparison with the BCC would be double or triple visual classification but such data were not available.

Carcass composition

The aim of the BCC was not only to predict EUROP classes but rather directly describing carcass composition more accurately than possible by indirect calculation from visual EUROP class and carcass weight. In this cutting experiment 75% of the variation in yield of saleable meat could be described by the BCC, figure 4.

Figure 4. **Saleable meat% predicted for 230 carcasses by the BCC, R^2=0.75, SEP=1.23.**

From the graph it is apparent that the prediction for young bulls is the most accurate app. 25% better. The BCC improvement of SEP over a prediction from visual EUROP classification was in the order of 7 to 14% for different composition parameters, figure 5.

Figure 5. **Differences in SEP for carcass composition determined by either neural networks in the BCC or from EUROP and weight.**

The variation in composition and the performance of either neural networks in the BCC or the model based on visual EUROP and carcass weight is shown in table 1.

Table 1. **Carcass composition traits, means, standard deviation, SEP and R^2 from either visual or BCC model, BCC SEP advantage over visual classification %, n=230.**

Discussion

Using neural networks in the BCC makes a significant improvement of the EUROP classification perfomance. Conformation was predicted much better, and almost all carcasses could be classified.

Neural networks obtain this advantage by incorporating large amounts of redundant data. The data are processed in parallel so that imperfections in some parts are compensated by other parts. This is analogous to the processing which is imagined to take place in the human brain. The classifier utilizes the total impression of the carcass to make his judgement of the grade. But contrary to the human brain the neural network does not change with time or place. Thus the BCC has combined the advantage of the stability and objectivity of a mechanical system with the intelligence of brain-like systems.

More consistent results are feasible with an objective calibrated equipment, as there are natural limits for calibration of human classifiers (Sørensen & Klastrup, 1987). Trained on the best reference the advantage of the BCC installed on all plants would be the objective basis, non-disputable results and likely a more uniform classification nationally.

Application of the new method produced also a clear advantage of the BBC for carcass composition. Prediction of composition is, however, still very difficult as only 75% of the variation can be described by the system. Compared to the roughly 50% reported for both the BCC and visual models by Sørensen et al. (1988), the method now seems much more appealing. The variation in composition in this dataset was 0.2 standard deviation unit larger for yield and bones compared to the 1988 data. Complete knowlegde of performance level demands supplementary cutting for certain categories. However, the differential in SEP between BCC and visual visual models is not expected to change.

Currently the BCC in Kolding is the only Danish installation and is used routinely for measurement of carcasses from breeding and feeding trials. Prior to a decision for further installations the Danish beef industry is in a process of deciding whether to integrate colour measurement of the fat cover (Madsen et al. 1993) as part of the equipment and improve other facilities of the 1987 concept technology. This implies some re-engineering and postpones installation.

Conclusion

BCC with neural network algorithms are well suited for beef classification based on carcass image data. Performance for EUROP classification is highly superior to linear models based on fixpoint measurements. The relation between classifier and BCC results is comparable to the visual agreement between two experienced classsifiers. Carcass composition is predicted with 7 - 14% lower SEP by the BCC compared to calculations from visual EUROP classification and carcass weight.

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