Iowa State University
Digital Repository

1997

Application of Newer Signal and Image-Processing Techniques for Ultrasound Beef Quality Evaluation Research

N. Kim
Iowa State University

V. R. Amin
Iowa State University

D. E. Wilson
Iowa State University

G. H. Rouse
Iowa State University

Follow this and additional works at: http://lib.dr.iastate.edu/beefreports_1996

Part of the Animal Sciences Commons

Extension Number: ASL R1331

Recommended Citation

Application of Newer Signal and Image-Processing Techniques for Ultrasound Beef Quality Evaluation Research

Abstract

More than 900 real-time ultrasound images from ribeye muscles across the 11th to 13th ribs of live beef animals were collected over the period of four years. Fat has acoustic properties appreciably different from those of other soft tissues, causing the transmitted ultrasound to be reflected from the interfaces between fat and muscle. As fat deposits (and hence marbling) increase, the speckle content of B-mode images also increased. Because speckle alters the texture of the image, intramuscular %-fat (IMFAT) can be estimated using texture analysis. A region of interest (ROI) was selected from the acquired image subjectively so that it contained a good image of the ribeye area between and above the 12th and 13th ribs. Image-processing techniques were applied for extracting features to analyze textures. The features showing good correlations with the actual IMFAT were used to develop statistical classification models. Because overall accuracy of prediction was improved by developing different regression models for the low-IFAT (less than 8%) and high-IFAT (more than 8%) groups (refer to R1325), statistical pattern recognition and classification techniques were applied to pre-classify the images into the low- or high-IFAT groups. The classification tree provided overall classification accuracy of 90% for lowand high- IFAT groups of images.

Disciplines
Animal Sciences

Application of Newer Signal and Image-Processing Techniques for Ultrasound Beef Quality Evaluation Research

N. Kim, graduate research assistant,
V. R. Amin, associate scientist, Center for
Nondestructive Evaluation and Animal Science,
D. E. Wilson, professor of animal science, and
G. H. Rouse, professor of animal science

Summary
More than 900 real-time ultrasound images from ribeye muscles across the 11th to 13th ribs of live beef animals were collected over the period of four years. Fat has acoustic properties appreciably different from those of other soft tissues, causing the transmitted ultrasound to be reflected from the interfaces between fat and muscle. As fat deposits (and hence marbling) increase, the speckle content of B-mode images also increased. Because speckle alters the texture of the image, intramuscular %-fat (IMFAT) can be estimated using texture analysis. A region of interest (ROI) was selected from the acquired image subjectively so that it contained a good image of the ribeye area between and above the 12th and 13th ribs. Image-processing techniques were applied for extracting features to analyze textures. The features showing good correlations with the actual IMFAT were used to develop statistical classification models. Because overall accuracy of prediction was improved by developing different regression models for the low-IFAT (less than 8%) and high-IFAT (more than 8%) groups (refer to R1325), statistical pattern recognition and classification techniques were applied to pre-classify the images into the low- or high-IFAT groups. The classification tree provided overall classification accuracy of 90% for low- and high- IFAT groups of images.

Introduction
Ultrasound tissue characterization involves the quantitative interpretation of information present in ultrasonic signals for diagnosis and monitoring of tissue. Ultrasound techniques non-invasively obtain information about the size, type, and structure of tissues in the body. Because the tissues of the body are inhomogeneous, the transmitted ultrasound interacts with the tissue components and is reflected and scattered by those tissues. The reflected ultrasonic waves, which contain information about the region being studied, can be displayed one-dimensionally (A-mode), or alternatively, several adjacent signals can be displayed two-dimensionally (B-mode). Wavelet transforms (WT), which are quite new signal and image-processing techniques, were applied for extracting features from ultrasound B-mode images. WT provided multi-resolutional spatial/frequency-localized information from images.

Previous works has shown that overall prediction accuracy was improved by developing different regression models for low-IFAT ($8\% \geq$) and high-IFAT ($> 8\%$) groups. Tree-based classification models were developed using selected features for pre-classifying images into low fat and high fat. A model provides multi-level non-linear classification model in the form of a binary tree. This report describes several newer feature extraction techniques and approaches for improving the accuracy and robustness of the classification models.

Materials and Methods
A commercially available real-time ultrasound system with a 17 cm 3.5 MHz linear-array transducer was used for live-animal scanning in the field. Ultrasonic B-mode images from more than 900 live beef animals were acquired by the ISU Animal Science research team from 1991 to 1994. The images were 512 pixels by 286 pixels in size and had 256 gray scale levels after acquisition. Because each image contained hide, subcutaneous fat, rib bone, and other anatomical parts apart from the ribeye muscle, a region of interest (ROI) was selected subjectively so that it contained a good image of the ribeye area between and above the 12th and 13th ribs. In this study, the size of ROI was 128 x 128, a form of the power of two, which is proper for discrete wavelet transform algorithms. Image processing using wavelet transform techniques was used to calculate features to quantify the image texture patterns. Wavelet transforms were obtained for a total of 207 images from which actual %-fats were available. WT divides an image into a smooth version of the image, a horizontal feature extracted image, a vertical feature extracted image, and a diagonal feature extracted image. Several features were calculated from those four kinds of subimages. The features showing strong correlations with actual IMFAT were used to develop a tree-based classification model.

For developing models and validation testing of %-fat prediction, the image data (207 images) were divided into two groups. The first group, with about 75% of available images, was used in the development of the prediction model. The second group of remaining images was used for validation testing of the classification model.

Results and Discussion
The chemically determined %-fat values for the 207 samples used in this study had a mean of 5.99%, standard deviation of 2.02%, and range from 1.1% to 11.86%. A correlation analysis between the actual %-fat values and extracted features from images was performed. A total of 14 wavelet-based features was selected, and they had very significant correlations with actual %-fat, with correlation

coefficients greater than .5 (p <.01). The features which are highly cross-correlated also were discarded in spite of their high correlation with %-fat. Table 1 shows the results of correlation analysis for a few features. The first line indicates correlation coefficients among several features and actual %-fat. The rest of the line shows the cross-correlation among features, and the values imply little mutual correlation.

Table 1. Correlation coefficients between selected features and actual intramuscular %-fat.

	Er	Edge	V33	K23
Fat	-.59	.52	-.62	-.50
Er	1.00	-.22	.67	.49
Edge		1.00	-.43	-.59
V33			1.00	.77
K23				1.00

A tree-based classification model was developed as a pattern recognition tool to assign each sample a class of less than or equal to 8% or higher than 8%. A total of nine random data set pairs was used.
A number of tree models were developed to get an optimum classification with different combinations of features. Results showed that an average classification accuracy of 84% was achieved with only one energy ratio feature (Er). When the number of features used for developing models was increased, the accuracy also increased slightly, as shown in Figure 1. Average classification accuracy was maintained at 90% with increment of the number of features used for the model developement. The results showed that the model with three features (Edge, Er. V33) provided the best classification accuracy (92%).

Implications
Texture analysis of ultrasonic B-mode images using wavelet-based analyses was investigated to predict actual intramuscular %-fat of live beef ribeye muscle. Wavelet transform provided spatial-scale localized information of ribeye texture images and provided several unique features to differentiate low-%-fat texture images from high-%-fat texture images. The texture features had very strong correlation with actual %-fat, many features were not highly cross-correlated with each other. These results indicate that wavelet-based features probably have a general applicability for a wide variety of image-classification applications.

The classification tree provided nonlinear multi-level analysis of variables and easy interpretation. Results showed that average classification accuracy was 90% for nine randomly selected training/testing groups with a few optimum feature combinations.

Figure 1. Classification accuracy of tree-based model with different number of features used for developing the model.