Applying Knowledge-Based Expert System to Meat Grading

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ABSTRACT
This paper briefly presents an on-going project, which has an immediate objective of developing a knowledge-based expert system to assist meat graders, and an ultimate objective of automating the meat grading process, through applications of image processing, pattern recognition, and expert systems. Presently, a voice-input, knowledge-based system for grading carcass beef has been developed and tested. The meat grader provides input for the system, in the form of carcass characteristics, by speaking into a microphone headset. Upon reception of the characteristics of the carcass, the knowledge-based system reasons through the production rules to reach quality and yield grades for the carcass.

INTRODUCTION
Assessing meat yield and quality in carcasses is important for the domestic consumer and for the export market. The U.S. livestock and meat industries rely on such assessment at all stages of the meat marketing chain from farm to retail sale [1], and depend heavily on the USDA to provide the rating of their meat for marketing. There is also a trend in the U.S. meat industry to process meat closer to the site of slaughter, because of increasing transportation and energy costs. Only the edible portion of the carcass will leave the slaughter plant. These trends will increase the volume of meat to be graded and the demand for more accurate, equitable and timely methods for grading meat.

Since the meat grading system started in 1927, meat has been graded by human graders. The method used to grade meat, while standardized, is very subjective and, because of this subjective nature, it is very difficult (if not impossible) to achieve consistency and equity. In a recent study by the USDA, Cross et al. [2] reported that the national percentage error of a selected three-member grading panel, evaluating 5592 beef carcasses from 56 plants and 11 mainstations, was 7.3 percent for quality grades and was 11.6 percent for yield grades. Both reports strongly recommended the development of instruments to assist human graders in evaluating grade factors. Since then, instrument grading has been studied to increase the accuracy and uniformity of meat grading. Cross et al. [3] used video image analysis (VIA) to predict the composition of a three rib section from 44 bullock and steer carcasses. They found that the equations developed using instrument-measured traits predicted the rib composition more accurately than non-instrument-measured traits. However, Wassenberg et al. [4] reported the same VIA had a predictive accuracy for yield of retail product weight of 95.6%, which was only slightly higher than the results of the selected three-member grading panel (94.3%). Other instruments and methods such as computer-aided tomography, nuclear magnetic resonance, electronic scanning planimeter, stereophotography, and ultrasonics have been studied. However, none of these systems have been sufficiently developed to be used commercially.

Current developments in Artificial Intelligence (AI) and Image Processing make it possible to devise systems for automated meat grading. AI is concerned with devising computer systems which are able to perform tasks that usually require human intelligence. More specifically, an expert system can solve problems based on specialized knowledge supplied by experts, coded into the program by knowledge engineers using AI languages, and reason, through the use of programs called inference engines, to reach the conclusions.

Although progress is being made in the instrument grading of meat, major barriers to automated meat grading are the availability of functional and compatible image processing, pattern recognition, and meat-grading expert systems.

The project being conducted at the U.S. Meat Animal Research Center (MARC) at Clay Center, Nebraska, has a short term objective of developing a knowledge-based expert system to assist meat graders, and an ultimate objective of automating the meat grading process, by applying the
technologies of image processing, pattern recognition, and expert systems.

**EQUIPMENT AND PROGRAMMING ENVIRONMENTS**

Livestock carcasses are scanned with a video camera or an ultrasonic scanner. The images obtained are then digitized, enhanced, and segmented and certain features of the image are extracted and analyzed using pattern recognition technology. Features of the carcass image are to be processed by a knowledge-based expert system with the result being carcass quality and yield grades.

Two vision systems are used to process the images: one is a Sun3/260C Workstation equipped with Datacube image processing hardware and the other is a Compaq Deskpro 386 computer equipped with Data Translation image processing hardware.

Knowledge-based vision systems are being developed to perform image enhancement, segmentation, and feature extraction. Resulting information is to be used by rule-based expert systems for determination of the yield and quality grades of the meat.

The 'C' Language Integrated Production System (CLIPS) and the Official Production System (OPSS+) programming environments, ported on the Sun3 Workstation, and the Personal Consultant Plus Expert System Shell (PC+), developed by Texas Instruments and ported on the Compaq Deskpro 386 System, are being used for developing the knowledge-based expert systems.

**PROGRESS**

A knowledge-based expert system for assisting meat graders has been developed. As configured, the meat grader provides the characteristics of the carcass to the computer. The computer, upon reception of the carcass characteristics, reasons through the production rules to reach the quality and yield grades. The production rules of the knowledge-based system are based on the meat grading knowledge described in the Official United States Standards For Grades Of Carcass Beef [6] and in the Meat Evaluation Handbook [7].

Research is being conducted with the aim of integrating the rule-based system and the image processing routines so that the images from the camera and ultrasound scanner can be used for grading. However, an alternate method that uses speech and voice recognition software to provide the necessary information has been developed and tested. Figure 1 is a block diagram of the voice-input, knowledge-based system for assisting graders.

**Knowledge-based subsystem**

PC+ was first used to develop the knowledge-based subsystem, which reads the characteristics of the carcass from the spoken words of the meat grader and determines the quality and yield grades of carcasses.

Quality grade and yield grade are the two goals which this knowledge-based system evaluates. The yield grade of the carcass is determined based on the values of the carcass weight, the backfat thickness on the exposed rib eye, the percent kidney, pelvic, and heart (KPH) fat, and the area of the rib eye. Based on subjective estimates, such as "very large rib eye", "large rib eye", "very small rib eye", entered by the grader, the knowledge-based subsystem is capable of determining proper values for the KPH fat and area of rib eye if specific values are not estimated and entered. The final yield grade is adjusted for subjective estimates of the rib eye size and any excess fat.

The quality grade is determined by the degree of marbling and firmness as observed on the cut surface of the rib eye, in relation to the maturity of the carcass. The meat grader enters the degree of marbling on the exposed rib eye.

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**Figure 1.** A block diagram of the voice-input, knowledge-based expert system for grading carcass beef.
The firmness of the lean tissue and the color of the rib eye area are the other two parameters used to determine quality. If they are not entered, the knowledge-based subsystem assumes that they are comparably developed with the degree of marbling, and the quality will be determined on maturity and marbling alone.

The maturity parameter can be given in three different ways. First, a letter grade such as A, B, C, D, or E can be entered. Maturity can also be determined by skeletal characteristics, such as the condition of the vertebral, rib bones, chine bones, and color and texture of the meat. This is useful when the grader cannot decide on a letter stage of maturity for the carcass, for example, because it is on the borderline between two stages. If no letter maturity or skeletal characteristics are entered, a default value of "A" is used for the stage of maturity. If the skeletal characteristics are given, they have a higher priority than the letter indication and will be used to determine the stage of maturity.

Voice-input subsystem

The VoiceScribe-1000 Speech Recognition System developed by Dragon System, Inc. of Newton, MA, was used. It is a 1000-word, speaker-dependent system that uses stochastic processing techniques. It matches a spoken word or phrase to a limited vocabulary of predefined words or phrases. This system allows each sound/symbol to be associated with an output string. The keyboard emulator recognizes the output string and turns it into simulated keystrokes which are treated by the computer as thought they came from the keyboard.

A grader must "train" the system to his or her voice for each word or phrase in the vocabulary. Voice patterns of these training words are stored in the system's memory and saved on disk for daily use.

Table 1 gives the phrases defined for use in a meat grading knowledge-based system. These phrases match the parameters used in the production rules programmed in the knowledge-based subsystem and are descriptive words taken from the Official United States Standards for Grades of Carcass Beef [6].

The vocabulary was divided into logical groups or menus of related characteristics for two reasons: first, if only part of the total vocabulary is active there are fewer words to compare the utterance to, thus increasing the speed of the matching process and secondly, similar sounding words that are unrelated can be put into different groups, reducing the risk of an incorrect match. Words and phrases that are frequently used are kept active at all times; otherwise, they are kept in a sub-menu and are activated only when necessary. For more details on the integration of the voice-input subsystem with the knowledge-based subsystem, see Chen and Robinson [8].

Program output

When the goals of the program have been reached, the results and the accompanying characteristics are stored in a permanent file with the identification number of that carcass as the file name, and the same data are output to the printer. After the output is given, the grader has the option of saying "enter" to continue for the next carcass or, if the grader is interested in knowing how the system reasoned to reach the result, the grader may select the option "HOW" and the specific parameters he or she is interested in.

Validation and performance

The development system in PC+ was used by a meat grader (unofficial) of the U.S. Meat Animal Research Center (MARC) to grade over 300 beef carcasses in the abattoir at MARC. These results were compared to the grades assigned to the same carcasses by an official meat grader from the Agricultural Marketing Service (AMS). The only differences in the grades given by the AMS meat grader and by the MARC meat grader were due to the differences in their assessment of the degree of marbling. Given the same characteristics as input, all the results were consistent, except the grade of one carcass which was misgraded by the AMS official meat grader, because of a factor not considered in reaching the final quality grade.

The MARC meat grader also graded 115 carcasses both with and without using the knowledge-based, voice-input meat grading system. All yielded the same results. However, in all the cases, using the computer meat grading system required much less time.
This development system required about 30 seconds for a meat grader to grade a carcass. About 20 seconds was used for vocal entry of the characteristics of a carcass and about 10 seconds for the computer to reach the conclusions and print out the grades.

Although this is much faster than the time used by the meat graders in the MARC abattoir (without using the system), where high accuracy is required, this is about one-third the speed (about 10 seconds per carcass) of a meat grader in a large commercial meat packing plant.

A new knowledge-based subsystem in CLIPS

In order to use the system in large commercial abattoirs, the system needs to perform processing in real-time. By coding the production rules in CLIPS, a new knowledge-based subsystem for grading meat has been developed.

The new system processes each carcass in real-time. The only time required for grading each carcass is the time for the meat grader to vocally enter the characteristics of each carcass and for the computer to print the results. The time required to grade a carcass can be further reduced as the grader acquires experience and becomes more familiar with the system.

Advantages of the system

This system requires a trained carcass characteristics inspector, with the computer doing the actual grading for quality and yield. This will relieve the grader from the intensive mental work in assigning the grades to the carcasses. Since the computer is doing the reasoning, grading accuracy would not deteriorate after long hours of continuous work.

Also since the rules are based on the specifications of the official meat grading rules, the resulting grades should always be as consistent or more consistent than those assigned by a human meat grader. This will result in more equitable grades. However, the consistency of the final yield or quality grades is dependent on the consistency of the meat characteristics observed by the trained inspector.

The rules are easily changed to implement new standards. Also, the meat characteristics and yield and quality grades are permanently recorded and processes involved in the decision making can be easily reviewed. This system can be used on the industrial livestock kill floor, and would also be very useful as a training tool for future meat graders.

CONCLUDING REMARKS

Current developments in Artificial Intelligence, particularly in the field of expert systems, will have a great impact on the way we use computers to solve problems, assist in decision making, or implement our research findings in practical uses. The use of artificial intelligence technology will broaden the horizon of computer applications in agriculture.

This paper described the on-going project at MARC on AI applications in meat grading automation and also presented a voice-input, knowledge-based system which was developed and used to assist meat graders. With a new knowledge-based subsystem programmed in CLIPS, it is possible to grade meat in real-time.

Research is being conducted to integrate the knowledge-based meat grading system with an intelligent vision system for meat grading automation.

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REFERENCES


