IEEE International Workshop on Intelligent Robots and Systems
IROS '90

130

AN INTELLIGENT AUTOMATED SYSTEM FOR DETERMINING PEANUT QUALITY

Floyd E. Dowell

United States Department of Agriculture, Agriculture Research Service
National Peanut Research Laboratory, Dawson, Georgia, USA

Abstract: A decreasing labor force and consumer demands for increased food quality has initiated development of an intelligent automated system for determining peanut quality. The system under development has the goal of removing all subjectivity involved in inspecting peanuts with minimal labor input. The system currently includes damage detection, bulk and single kernel moisture determination, positive sample identification, a chemical test for aflatoxin, and automated feeding, conveying, sorting, weighing, and data recording. All components are controlled by and feed back to an expert system. An estimated 50% reduction in labor can be achieved with this system. More importantly from a quality standpoint, 100% of the subjectivity is removed when determining aflatoxin values and freeze damage. Current work focuses on improving identification of other types of kernel damage, identifying foreign material, and integration of devices to indicate flavor.

1. INTRODUCTION

The agricultural industry is probably to oldest and most widespread industry in the world. The labor intensive procedures generally required for production, marketing, and processing agricultural commodities has typically been carried out by large numbers of unskilled laborers. However, a decreasing labor force and consumer demands for higher quality foods are dictating changes in many United States (US) agricultural industries. A decreasing labor force dictates more automated procedures and increased quality dictates more objective and accurate quality measurements. The peanut industry is no exception. Foreign markets get more competitive each year, both in quality and price, and the US peanut industry realizes the foreign buyers can go elsewhere if we do not meet their standards for quality. Also, a more educated consumer, provided with alternative products, can switch to those other products if their demands for peanut quality are not met.

Recent quality problems, perceived or real, in the US (pesticide residues in apples), Chile (cyanide residues in grapes), and Europe (chemical residues in Perrier) illustrate what can happen if adequate product quality control is not maintained. Each of these industries encountered substantial losses and may never regain their original markets. Thus, all portions of the peanut industry are striving to adopt or develop practices to insure the quality of US peanuts to prevent the peanut industry from experiencing similar mishaps. Therefore, determining peanut quality accurately and objectively is of paramount importance.

The existing peanut grading system used to determine quality in samples of peanuts has evolved from a system with no mechanization (5) to the existing system which includes operator assisted equipment that aid in determining quality (6, 11). However, this system is still labor intensive and very subjective during several steps in the grading process. The existing system involves obtaining a 1800 g grade sample from about 4 tons of peanuts at farmer marketing, determining the foreign material and loose shelled kernels in this 1800 g, and determining the sound mature kernels, sound split kernels, damaged kernels, oil stock kernels and moisture content in 500 g of pods taken from the 1800 g grade sample. All kernels are examined for the presence of carcinogen producing molds. Figure 1 shows the existing grading system schematic with the labor intensive and subjective portions identified.

A labor force of about 2000 workers is required each year to inspect the approximately 1.6 million metric tons of peanuts produced each year in the US. The inspectors are required to make several judgements in determining quality and the stricter standards being imposed by domestic and foreign buyers, particularly with regard to damage and aflatoxin, make it more difficult if not impossible to find and train qualified personnel to make these quality determinations. Even with properly trained personnel, some variability between inspectors and even variability with one inspector over several days makes it difficult to improve the existing grading system. In addition, the peanut industry is requesting a larger sample be graded to improve the accuracy of predicting peanut quality. Grading a larger sample will further increase labor requirements. Moreover, additional quality determinations, such as flavor potential, need to be incorporated in the grading system. For the above reasons, the peanut industry has requested that an objective automated system for grading peanuts be developed.

2. BACKGROUND INFORMATION

Automated inspection techniques are currently used successfully in other industries and are often centered around a machine vision

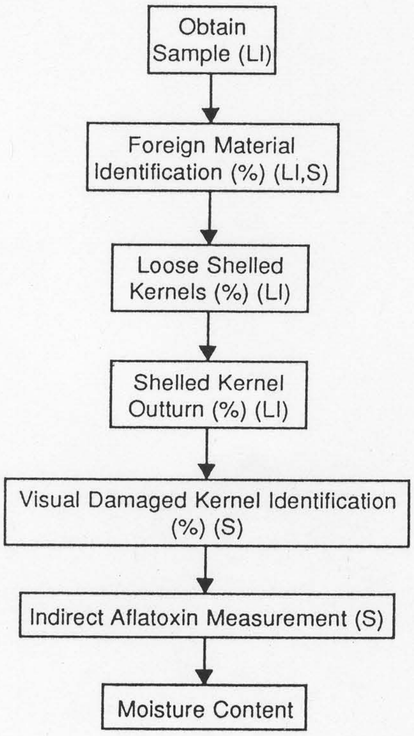

Figure 1. Current peanut grading system with the labor intensive (LI) and subjective (S) portions identified.

system. Goldstein and Nagler (7) inspected 300 metal parts per minute for structural and textural defects with machine vision. Petty (12) described checking pharmaceuticals for debris and contamination, inspecting printed circuit boards for holes, and aligning injection moulding tools using machine vision.

Based on the success of automated inspection in other industries, it stands to reason that machine vision can be used to inspect agricultural commodities. Casady and Paulsen (2) developed a machine vision centered system to inspect and sort corn kernels based on surface defects. Rehkugler and Throop (13) developed a feeding and machine vision inspection system for apples.

Barrett and Jones (1) tie together how an expert system can be used to make decisions that result in the automatic control of sensors, machine vision equipment, and other machinery. Newton et al (8) describe how an expert system can be used to control agricultural equipment.

Although a complete system for the automated inspection of commodities is not commercially used in the agricultural industry, much of the technology needed to develop the system exits. Thus, the goal of developing an intelligent automated inspection system for peanut grade sample was established. Existing technology was to be used when applicable and research undertaken where technology is lacking.

3. SYSTEM DEVELOPMENT

The ideal peanut inspection system is one where all peanuts are inspected and accurate quality factors determined without any human intervention (Figure 2). A long term research program was started in 1987 with the goal of developing this automated objective system. Although the complete system may not be available for some time, portions of the system are being developed and implemented. The information reported here describes the completed portions of the system and development that is in progress. Figure 3 shows a flow chart of the proposed intelligent automated system.

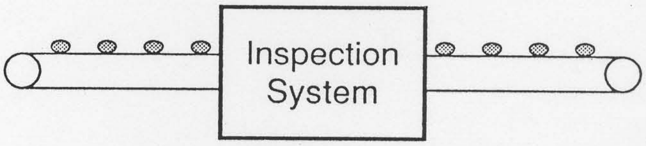

Figure 2. Ideal peanut inspection system.

The current automated system development focuses on shelling and inspecting a sample taken from a larger population of unshelled peanuts. A sample, instead of the population, is graded for reasons relating to cost and storability of the peanuts. Currently, farmer marketed peanuts are stored in the shell to maintain quality. Once the peanuts are shelled, the quality is more likely to deteriorate when stored. Therefore, it is not desirable to inspect all peanuts unless this can be done without shelling. Also, grading a sample from the population greatly reduces the cost and requirements of the inspection system. The confidence associated with predicting the population quality can be determined (4).

Software

The automated system is controlled by a expert system written in 'C' programming language. The expert system controls as well as receives feedback from the instruments shown in Figure 4. After the grade sample inspection is completed, the program uses the appropriate information to compute the quality and dollar value of the peanuts. The decisions made by the expert system are based on Federal-State Inspection Service standards (6) and on current marketing schedules. By basing the decisions on standards, any number of intelligent automated systems can be programmed to make the same quality determinations on a set of peanuts, therefore eliminating judgement errors by inspectors.

Quality Detection Hardware

The following quality parameters currently provide input to the expert system: kernel damage, kernel size, single kernel moisture content, bulk moisture content, and aflatoxin values. Research to include a flavor indicator and foreign material piece count and type identification is underway.

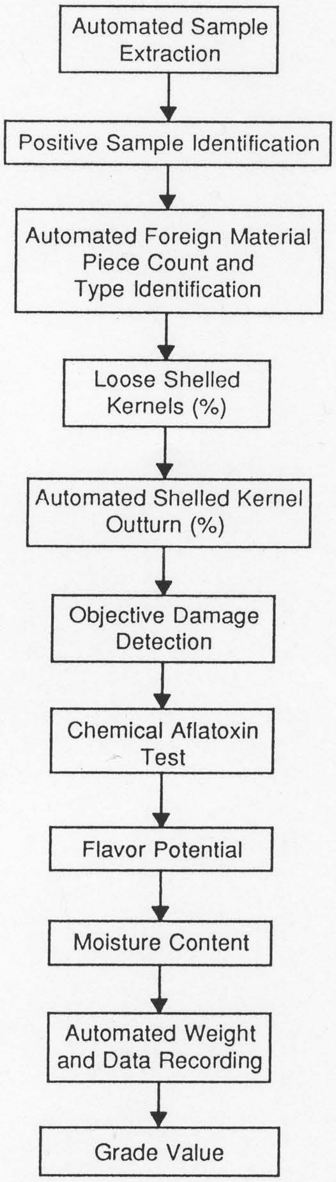

Figure 3. Intelligent automated inspection system.

In the old grading system, inspectors are trained to look for kernel damage, resulting in subjective decisions. In addition, size is determined using stamped screens with tolerances as large as 0.254 mm. With the automated system, kernel size and damage are determined using a machine vision system and a colorimeter. Kernel size is determined using the machine vision system by finding the maximum diameter of the minor axis of the kernel with an accuracy of plus or minus 0.0254 mm. The machine vision system is capable of 512 by 512 pixel resolution and processes in real time. The system contains a frame buffer module, an analog to digital interface module, and a pipeline processor module. Two white light projectors equipped with adjustable lenses are used to illuminate the kernels. A black and white tube type camera is used to view the objects in two dimensions. About 3 seconds are required to calculate the kernel size.

Kernel damage is determined using grey level and texture information obtained from the digitized image of the peanut kernel. Damage computations can be made in about 3 seconds with the machine vision system. Additional damage information is obtained using a colorimeter. Hue, lightness, and saturation information is used to classify several categories of kernel damage. A built in pulsed xenon arc lamp provides consistent uniform illumination. Color values are determined in about 1 second.

Bulk peanut kernel moisture content is determined in the old system on about 150 g of kernels using a DC conductance type moisture meter and manually recorded on the grade sheets. The existing moisture meter now inputs to the expert system where the data is automatically recorded and the appropriate calculations made. In addition, procedures were developed and modifications made to adapt a DC resistance single kernel moisture meter to peanuts. Determining single kernel moisture will determine if peanuts have been improperly dried or if wet and dry peanuts have been mixed. About 75 g of peanuts are used in the single kernel moisture meter. As with the bulk moisture, the single kernel moisture is automatically recorded by the expert system.

An indirect measurement of aflatoxin, a carcinogen produced by naturally occurring molds, is made in the old grading system by visually inspecting the kernels for the mold. Cole et al (3) showed that the visual method is a poor indicator of aflatoxin, thus, in the interest of food quality, a chemical test was included in the automated system. A fluorometer sends aflatoxin values in parts per billion resulting from the chemical test to the expert system.

The old system has no provision to estimate the flavor potential of the kernels. The new automated system will include an alcohol meter which indicates improperly cured or off-flavored peanuts (9). The meter will send headspace volatile concentrations, which indicate flavor, to the expert system.

Sorting Hardware

Kernels are sorted into their respective areas depending on their size or damage characteristics using a feeder, conveyor and sorting gate. A single kernel feeder places kernels on a 15.2 cm wide and 183 cm long conveyor. The belt is driven by a variable speed motor that turns the belt at 0 - 5 cm/s. A photoelectric switch senses the kernel and triggers the imaging system to snap an image to be processed. After processing, the kernel size and damaged characteristics are determined. Based on this decision, a solenoid activated sorting gate diverts the kernel to the appropriate location. All sorting hardware is integrated with the expert system through input and output modules on an automatic controller.

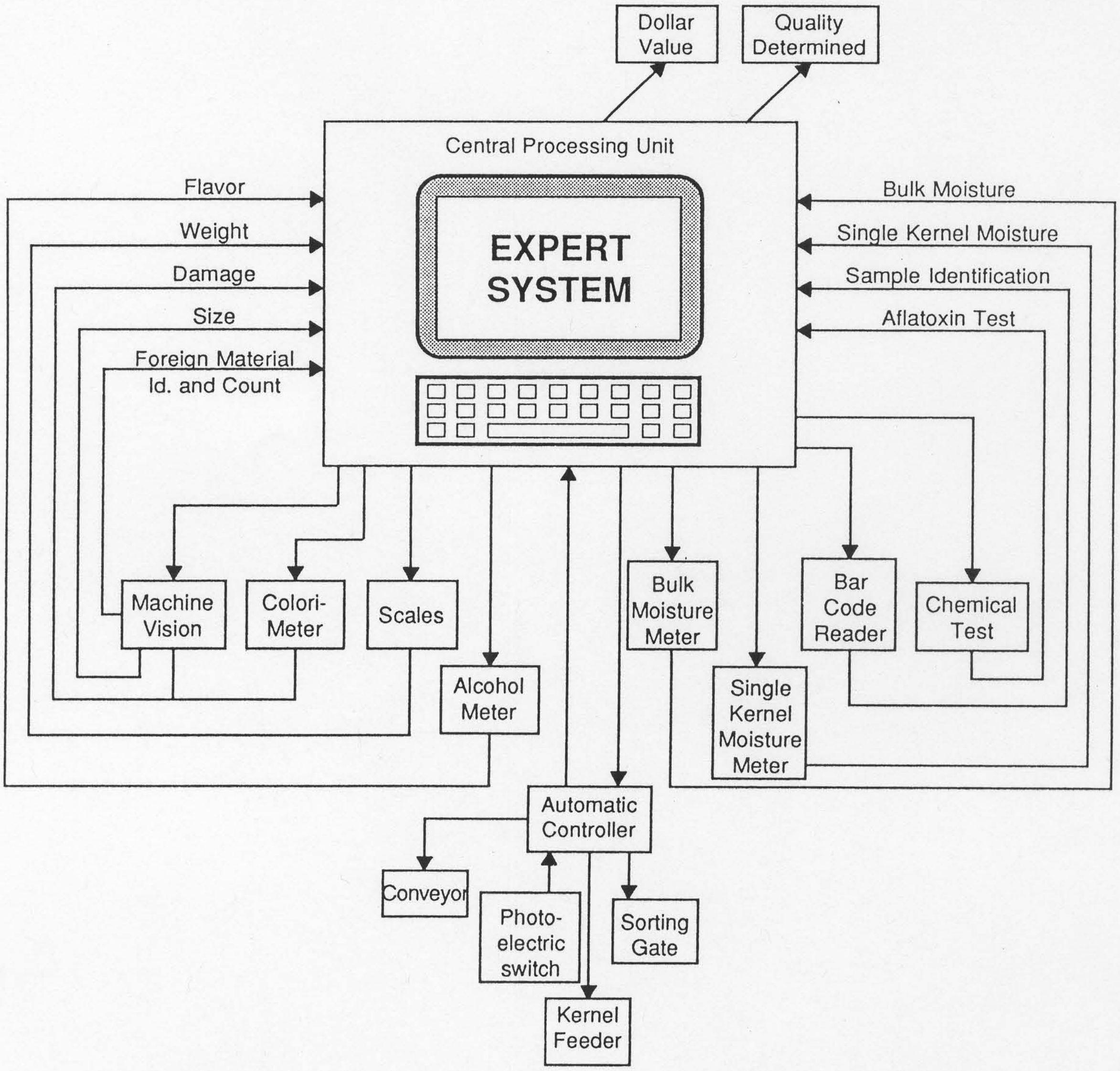

Figure 4. Control loops for an automated inspection system for peanuts.

Recording Hardware

Equipment such as the moisture meter and fluorometer send values directly to the expert system for recording on the central processing unit. In addition, scales and a sample identification system are used to record data on the central processing unit. A bar code reader is used to identify the sample and the particular category being recorded (i.e., foreign material weight, damaged kernels, moisture content, etc). The bar code originates when the sample is first weighed and the sample identification entered on the scale keyboard. The bar code follows the sample through the grading process. This minimizes input errors by having the sample identification number entered only once. Scales send weight values to the expert system. All computing occurs on a 80386 computer with a 40 megabyte hard drive.

All peripheral devices send data to the expert system through a communications link. The communications link allows up to 16 devices to input information to the expert system. The communications program and link are structured such that multiple inputs from external devices can be simultaneously sent and recorded by the expert system. The expert system can receive, display, and save data from multiple samples moving simultaneously through the grading system. The expert system can account for samples that are processed out of sequence and will not save the information until all data is recorded for each sample.

4. SYSTEM PERFORMANCE AND FUTURE WORK

Current research shows that an approximately 50% reduction in labor can be achieved with the automated system. More importantly from a quality standpoint, 100% of the subjectivity is removed when determining aflatoxin values and freeze damage. Extensive testing of the expert system receiving input from the scales, bulk moisture meter, single kernel meter, bar code reader, chemical test equipment, and colorimeter is in progress and extensive field testing is planned for the Fall 1990 harvest season. The expert system will calculate grade values and quality parameters based on the inputs. The field testing will occur in conjunction with testing automated sample cleaning, shelling, sizing, and splitting equipment currently under development. Research towards improving identification of other types of kernel damage, identifying foreign material, and integration of the alcohol meter is underway.

Food quality is an area ever increasing in importance as consumers become more quality conscious. In addition, cost saving through decreasing labor requirements is essential to keep peanut product prices at consumer acceptable levels. Thus, the intelligent automated system described here offers the potential to remove the human subjectivity from the grading process to insure the quality of US peanuts and to reduce labor costs. Also, certain procedures such as more accurate kernel sizing and foreign material identification are now possible with the recent advancements in technology. Although a completely automated intelligent grading system may be several years away from being implemented for cost and technological reasons, portions of the system are now cost effective can be implemented within the next year to help ensure the quality of US peanuts for our domestic and foreign markets.

The author thanks Harry T. Sheppard, Engineering Technician, and James H. Powell, Computer Programmer, for their assistance and expertise in this project. This research was funded in part by a grant from the National Peanut Foundation and the Georgia Agricultural Commodity Commission for Peanuts.

5. REFERENCES

(1) Barrett, J. R. and D. D. Jones. 1989. Knowledge engineering in agriculture. ASAE Monograph No. 8. Am. Soc. of Agric. Eng., St. Joseph, MI 49085.

(2) Casady, W. W. and M. R. Paulsen. 1988. An automated kernel positioning device for computer vision analysis of grain. ASAE Paper No. 88-3051. Am. Soc. of Agric. Eng., St. Joseph, MI 49085.

(3) Cole, R. J., J. W. Dorner, J. W. Kirksey, and F. E. Dowell. 1988. Comparison of visual, enzyme-linked immunosorbent assay screening, and HPLC methods in detecting aflatoxin in farmers stock peanut grade samples. Peanut Science 15:61-63.

(4) Davidson, J. I., Y. J. Tsai, R. J. Cole, J. W. Dorner, and F. E. Dowell. 1988. Variability in sampling and grading Florunner farmers stock peanuts. APRES 20:22. (Abstr.)

(5) Elliott, T. A. and B. W. Carmichael. 1955. Efficient picking, transporting, handling, storing, and shelling of farmers' stock peanuts. Annual Progress Report. Project No. 147. Georgia Institute of Technology.

(6) Farmers' Stock Peanuts Inspection Instructions. Revised July 1988. USDA, AMS, Fruit and Vegetable Div., Fresh Prod. Branch, Washington, DC.

(7) Goldstein, M. D. and M. Nagler. 1987. Real time inspection of a large set of surface defects in metal parts. Proc. of SPIE - The International Society for Optical Engineering, Cambridge, MA, 849:184-190.

(8) Newton, K. A., M. L. Stone, and H. W. Downs. 1986. Reducing grain losses of a combine's cleaning unit by an expert system. ASAE Paper No. 86-1579. Am. Soc. of Agric. Eng., St. Joseph, MI 49085.

(9) Pattee, H. E., E. W. Rogister, and F. G. Giesbrecht. 1989. Interrelationships between headspace volatile concentration, selected seed-size categories and flavor in large-seeded Virginia-type peanuts. Peanut Science 16:38-42.

(11) Pattee, H. E. and C. T. Young. 1982. Peanut science and technology. Am. Peanut Res. and Ed. Soc., Inc.

(12) Petty, M. S. 1982. Image analysis for product inspection at low cost and high speed. Proc. 6th International Conference on Automated Inspection and Product Control, Birmingham, UK, pp. 149-160.

(13) Rehkugler, G. E. and J. A. Throop. 1986. Apple sorting with machine vision. TRANSACTION of ASAE 29(5):1388-1397