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AUTOMATED INSPECTION OF PEANUT GRADE SAMPLES

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Evaluation and modification of the U.S. peanut grading system is occurring in response to consumer and industry requests. In a meeting of farmers, sheller, manufacturing, government, and state representatives held in Washington, DC, in November 1989, the following changes in the grading system were among those identified as high priority areas needing to be addressed: labor reductions, a larger sample size, objective damage detection, foreign material piece count and type identification, detection of chemical residue, and moisture content range (Sanders, 1989). Recent technological advances in machine automation and computer based inspection systems may address some of these needs.

Machine vision inspection of agricultural commodities provides the potential to reduce labor costs and to more consistently and accurately determine the quality factors that inspectors are currently trained to evaluate. In addition, some characteristics of commodities, such as size, can be more accurately determined using machine vision than by using mechanical methods (Dowell, 1989). The objective of this research was to develop low cost, computer controlled feeding and sorting mechanisms integrated with a machine vision system as an intermediate step in developing an improved grading system for peanuts. Machines to reduce labor involved in shelling and removing foreign material from samples are also being developed as part of an automated system.

LITERATURE REVIEW

Casady and Paulsen (1988) developed a feeding mechanism to feed corn kernels to a machine vision system. The system utilized a mechanical linkage which moved the kernel from a conveyor belt into the field of view of the camera. An air jet diverted the kernel based on the decision made by the computer.

Rehkugler and Throop (1986) developed a feeding system for apples, but it does not lend itself well to small seeds. Maenpaa et al. (1982) developed a high capacity automation inspection system utilizing a conveyor belt to feed a machine vision system for sorting rocks from limestone. A line scan camera viewed the objects and an air blast diverted rocks from the limestone. The conveyor operated at a speed of about 5 m/s and 120 tons/hr of rocks and limestone were processed. Misclassification errors were 1-2%.

Atkinson and Heywood (1982) identified machine vision as a possible solution for the identification of foreign material in food products because other conventional forms of identification have failed.

Green (1985) describe lighting and machine vision software requirements for the automated inspection of meats and packaged goods. Mersch (1986) and

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Novini (1986) describe lighting configurations, lighting sources, and filtering techniques for the automated inspection of objects. Hill (1985) describes procedures for measuring light levels. McFarlane (1985) described the application of machine vision to the food industry through the measurement of product thickness. Petersen and Even (1986) gave an overview of machine vision technology, including hardware requirements and image enhancement techniques.

PROCEDURES

The development of an automated inspection system is being carried out in two phases: (1) developing a machine vision based inspection system to determine quality factors, and (2) development of machinery to prepare the sample for inspection. This includes sampling, removing foreign material, and shelling.

The machine development for the second phase is currently under way; therefore, only the machine vision portion of the automated inspection system is discussed here. The areas that will be discussed are: (1) development or purchasing of electrical and mechanical components to feed, sort and weigh the peanuts, (2) integrating these components with the computer, and (3) writing software to allow the machine vision system to communicate with the mechanical components. A fourth, and very important thrust, is the optical arrangement of the machine vision system and the development of the algorithms to determine specific grade factors. This fourth area is discussed briefly, but cannot adequately be covered here and will be the subject of subsequent papers.

Electrical and Mechanical Components

A single kernel feeder from a peanut planter is used to place the kernels onto a Roach conveyor. The conveyor has a 15.2 cm wide and 183 cm long track (Fig. 1). Depending n the quality factor being determined, either a 120 PVC black friction belt or a Dorner #1 FDA approved hard top accumulator white belt is used. Both belts have low reflectance characteristics. Belt speed can range from 0 to 5 cm/s through the use of a Dayton Model 22797 variable speed motor.

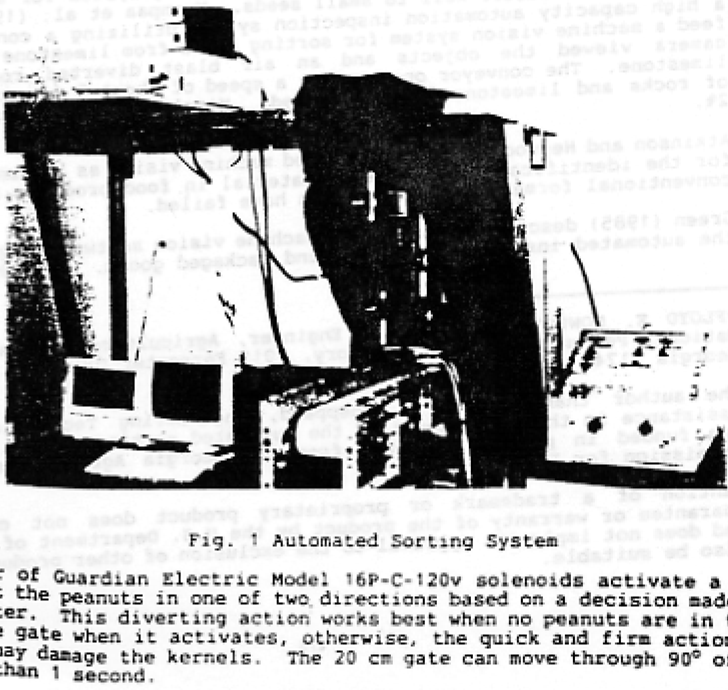

Fig. 1 Automated Sorting System

A pair of Guardian Electric Model 16P-C-120v solenoids activate a gate to divert the peanuts in one of two directions based on a decision made by the computer. This diverting action works best when no peanuts are in the path of the gate when it activates, otherwise, the quick and firm action of the gate may damage the kernels. The 20 cm gate can move through 90° of arc in less than 1 second.

Scales can be positioned at the end of the belt and linked to the computer to automatically weigh the sorted objects. The Mettler Model SM6000 scales contain an RS232 port that allows communication with a computer. The object is carried by the conveyor to the imaging area where it is detected by an OMRON Model E3F-R2Z2 photoelectric switch which indicates to the vision system when an object is in the field of view.

Hardware-Software Integration

All hardware is integrated with the computer through a Metrabyte MSS/MDI-16 driver board. A ribbon cable connects the driver board with a board placed in an expansion slot of the computer. Input or output modules connect each component to the driver board. The components are all wired for either manual or automatic controlling. The exception to the hardware integration is the scales which are connected directly to the communication port of the computer. A schematic of the wiring is shown in Fig. 2.

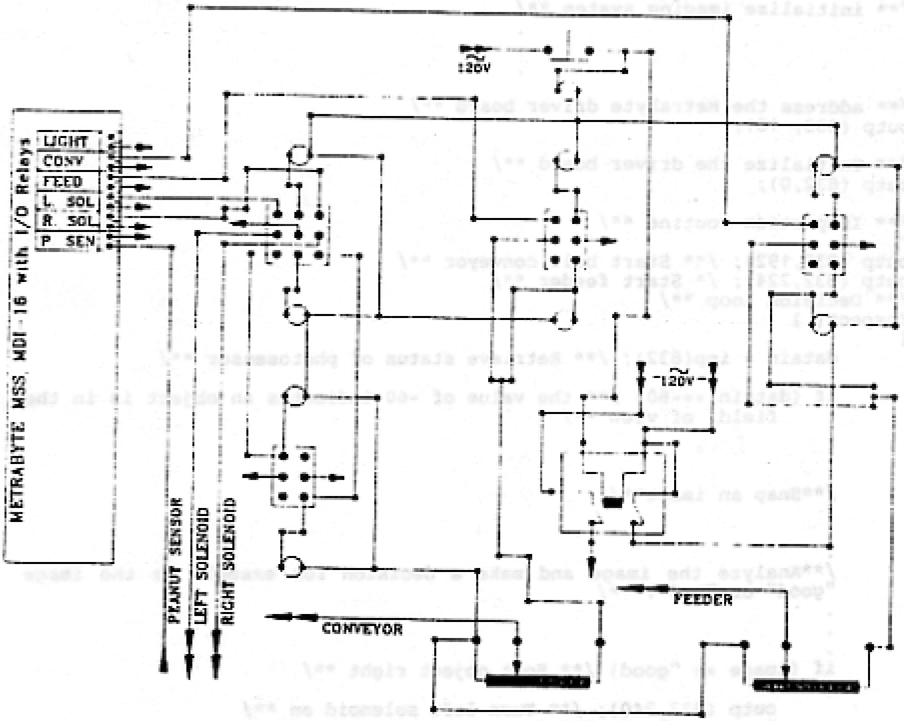

Fig. 2 Wiring Diagram for Controlling the Automated Inspection System Hardware

Machine Vision Specification

The machine vision system is capable of 512 horizontal by 512 vertical pixel resolution. Real time imaging or the ability to process 250,000 (512 x 512) bytes of information in 1/30th of a second (the camera scan rate) is achieved by using an Imaging Technologies, Inc. Model 151 imaging system. The system contains a frame buffer module, an analog to digital interface module, and a pipeline processor module. A Compaq Model 40 portable 20 MHz computer with an 80386 processor controls the imaging system and the Metrabyte driver board for the automated hardware. Newport Model MP1000 white light projectors illuminate the objects and a Dage Newvicon MTI-65 tube camera views the objects. The white light projectors mounted on either side of the camera aim at the object to be illuminated. Arokinon f 28-85 mm camera lenses mounted on front of each white light projector provide excellent control and balance of lighting conditions. All programming utilizes Microsoft 'C' language.

The lights and camera were mounted on Newport Corporation adjustable rods and tracks. The Newport Corporation table and mounting equipment allowed for excellent control of camera and light placement. An 18 oz. black vinyl tarp enveloped the camera, lights, and a portion of the conveyor to eliminate variations in ambient lighting conditions.

<u>Software Requirements</u>

Specific image analysis routines specific to this application will be discussed in subsequent papers. Only general programming requirements needed to allow the computer imaging system to communicate with the mechanical components are discussed:

Figure 3 outlines procedures for a program using 'C' language and communicating with the Metrabyte driver board. The routine automatically starts the inspection system and runs until the user terminates the program. The sorting equipment must be manually shut down.

```
      .
      .
      .
/** initialize imaging system **/
                                                  .
                                                  .
                                                  .

/** address the Metrabyte driver board **/
outp (833, 16);

/** Initialize the driver board **/
outp (832,0);

/** Inspection routine **/

outp (832,192); /** Start belt conveyor **/
outp (832,224); /* Start feeder **/
/** Decision loop **/
Inspect( )
{
       datain = inp(832); /** Retrieve status of photosensor **/

       if (datain ==-60) /** the value of -60 indicates an object is in the
             field  of view **/
       .
       .
       .
       /**Snap an image**/
       .
       .
       .
       /**Analyze the image and make a decision for example is the image
       "good" or "bad"? **/
       .
       .
       .
       if (image == "good) /** Sort object right **/
       {
             outp (832,240); /** Turn left solenoid on **/
             for (x = 0; X< 30000; x++)
                   /** Time delay to allow gate to move full
                   distance **/
             outp (832,224); /** Turn solenoid off **/
       }
       if (image == "bad) /** Sort object left **/
       {
             outp (832,232); /** turn right solenoid on **/
             for (X=0; X< 30000; x++)
                   /** Time delay to allow gate to move full
                   distance **/
             outp (832,224); /** Turn solenoid off **/
       }
 datain = 0; /** Reinitialize status of photosensor variable **/
 inspect( ); /** Continuously loop through inspect( ) routine **/
 }
```

Fig. 3 Program Schematic to Allow the Decision Making Software to Communicate With the Inspection System Hardware.

DISCUSSION

The complete system described here serves as a reliable and low cost inspection system. In addition, the flexibility of the system makes it an excellent tool for testing new hardware or image processing and analysis routines. The Metrabyte driver board can control up to 128 devices, and the Newport table and accessories can provide almost unlimited adjustments and arrangements of lights and cameras. The system views two dimensions of the kernel.

If this system is to be used for other products, some considerations need to be made. Since the objects are moving with the belt when the images are acquired, some blur and field displacement occurs. The tolerance allowed in the decision being made will determine what actions, if any, need to be taken to minimize these errors. Blur can be reduced using strobe lights or, more easily, by shuttering the camera. The amount of blur that can be tolerated will dictate the shutter or strobe speed. However, when shuttering or using a strobe light, only half of the frame, either the odd or even field, is grabbed and the vertical resolution is cut approximately in half. Some cameras are available which enable the entire frame to be transferred rather than one field and then the other.

Field displacement is caused when a moving image is grabbed by the imaging system. One field, say the odd field, is transferred to the imaging system, then as the camera is resetting, called vertical blanking, the moving object displaces slightly before the even field is transferred. This appears on the monitor as a jumping or shaking image. Acquiring only one field eliminates the field displacement, but the vertical resolution is cut in half. When acquiring one frame, the object will not appear displaced, but if shuttering or strobing is not used, a moving object will still appear as a blurred image (Swensen and Attle, 1979).

The system described here utilizes only one field to eliminate field displacement errors. Preliminary testing shows the kernels can be sized to ±0.0254 mm (0.001 inches) by finding the maximum diameter of the minor axis of a two-dimensional image. For damage determination, optical filters are used to enhance the damaged portions of the kernels. After acquiring the image, the discoloration, based on grey levels, is determined. Currently, one 2-dimensional view of the kernel is being processed. The percent of the surface area discolored is then determined because greater than 25% of the kernel must be discolored according to FSIS standards (Farmers' Stock Peanuts Inspection Instructions). Additional damage detection routines and foreign material identification are being developed. The complete system can automatically inspect and sort an object every 3 seconds.

At this point, the software is the rate limiting step followed by the sorting mechanism. More efficient programming or more hardware intensive computations can significantly reduce the computation time. Future efforts will focus on developing a three-dimensional viewing apparatus and reducing computation time. However, the system serves well as a low cost, flexible means of testing new ideas. The basic design should serve as a building block to other researchers who desire to build a prototype feeding and sorting system for their automated inspection applications.

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