

A New Control Approach for Tomato defect sorting with Machine Vision System

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ABSTRACT

This paper describes a new approach of control for a Machine Vision System applied to sort defective tomatoes. For this purpose Matlab 7.0 is used to develop the controlling algorithm. This approach is new because usually control is done by C programming. But for Modern Operating Systems like Windows XP and 2000 it is difficult to use C program directly for control. So this paper introduces a new technique of controlling a Machine Vision System for sorting of tomatoes using data acquisition toolbox of Matlab 7.0. In this system parallel port is programmed to control the defect sorter through a simple interfacing circuitry. The performance of the defect sorting through the control system has been found to be 5 tomatoes/sec, which is economic in automatic fruit sorting and detection process.

Keywords: Machine Vision System, Control Algorithm, and Defect Sorter.

1. INTRODUCTION

With the advances of the computer technology most of the automations in the Machine Vision systems are changing. The way to control of Machine Vision system indicates the efficiency of the system. The more adaptation of the system software to the control algorithm the more is the response from a Machine Vision system. Usually the Control algorithms are developed with C programming language, which runs on MS DOS operated PCs. The most of the image processing algorithms of a Machine Vision system is developed by high-level languages like Visual C++ or Matlab, which runs on high speed PCs with modern operating systems.

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In order to integrate all the algorithms for Machine Vision system unique control architecture is needed.

Machine Vision Control architecture senses the inputs of the sensors in the form of visual information from the specified port of the controller and gives the desired response to the actuators to sort the defected fruits in case of fruit inspection.

For this competitive age of technology we should look forward to develop our controlling system using some algorithm or software, which can be developed fast and implemented in a real application. Now a day, the computing systems and its operating systems also changing so the controlling systems should match with it and run fast. To meet these requirements we are proposing a new technique to control a real application like defect sorter by programming the parallel port using Matlab [1].

Parallel port is a simple and inexpensive tool for building computer controlled devices and projects. The simplicity and ease of programming makes parallel port popular in electronics world [2]. The parallel port in the original IBM PC, and any port that emulates the original port's design, is sometimes called the *SPP*, for standard parallel port, even though the original port had no written standard beyond the schematic diagrams and documentation for the IBM PC [3]. PC parallel port is 25 pins D-shaped female connector in the back of the computer. It is normally used for connecting computer to printer, but many other types of hardware for that port is available today [4]. MATLAB and the Data Acquisition Toolbox create a unique environment to communicate with a digital device. MATLAB provides us with a simple programming language to construct and build the logical framework necessary to drive the digital device. In addition MATLAB offers a variety of tools to construct the graphical user interface. The Data Acquisition Toolbox provides support for communicating with digital devices through the digital input/output or DIO objects. The R13 release of the Data Acquisition Toolbox now includes a parallel port adaptor that enables us to use the parallel port as 17 lines of digital input and output. The advantage of using a DIO object in MATLAB is that the DIO object is portable across supported hardware, assuming that the hardware provides similar capabilities [5].

2. BACKGROUND

In review of the control approaches used so far we have seen that most control systems in Machine Vision used PC (Personal Computer) s or DSP (Digital Signal Processor) as controller, which

is based on C or Visual C++ Languages and fruits are sorted according to algorithms by a sorting unit. Machine Vision System consists of CCD (Charged Coupled Device) cameras or NIR (Near Infra Red) cameras, Fruit handling unit, Inspection Chamber and fruit sorting unit. M. A. Shahin and S. J. Symons [6] developed an Instrumental Colour and Size Grading of Pulse Grains. The pulse grading system consists of a PC, a flatbed scanner as sensor and a Graphical User Interface (GUI) for input/output (I/O) purposes for control. The GUI was implemented in Visual Basic. The control algorithm is based on commercial software written in C. N. Aleixos, J. Blasco, F. Navarro'n, E. Molto [7] developed a Multispectral inspection of citrus in real-time using machine vision and digital signal processors. The architecture of the software has been developed to run over two DSPs, in a master/slave configuration, working in parallel. The algorithms were implemented, and the application was simulated on the development board. The system has a 60 MHz clock and a *read only memory* (ROM) to perform the initial program and data load in the master processors. The program and data load for the slave processor is done by means of a *direct access memory* (DMA) from the master processor. Once the master processor has sent the last strip of the fruit to the slave processor, it awaits for the results of the surface analysis to pass all the data to the system control, which decides the quality and delivers the fruits to the corresponding boxes.

Zhiqing Wen, Yang Tao [8] developed a rule-based machine-vision system for defect inspection on apple sorting and packing lines. For controlling, a roller conveyor is used to support, rotate and move apples and an optical encoder is used for providing the timing signal for on-line mechanical and electronic synchronization. Control algorithm is based on the activation of the procedural KS (Knowledge Source), which is controlled by the host computer as well as the rule-based KS.

J. Blasco, N. Aleixos, E. Molto [9] developed a Machine Vision System for Automatic Quality Grading of Fruit. In this work, robotic system is used for automatic inspection, handling and packing of fruits. Control algorithms are based on specific software run under disk operating system (DOS). S. Laykin, Y. Edan [10] developed a Quality Sorting Machine Using Machine Vision and Impact. The Impact algorithm for control is such that the highest peak of the force vector occurs when the fruit first lands and reaches its maximum deformation. Later it may bounce once or twice within the duration of the data acquisition, forming additional distinct

peaks, each lower than the previous one. Integration of this function indicates the amount of energy lost in each impact. A softer fruit will stay in contact with the surface for longer, reaching a lower peak force and bounce to a lower height and therefore land again sooner.

Lee, Slaughter and Giles [11] designed a Robotic Weed Control Systems for tomatoes. A robotic cultivator was used as a guidance system to center the weed control system over the row. An encoder generated a pulse whenever the tractor moved forward. A micro controller was used to count pulse of the encoder to determine the location of the tractor. A sensor watch communicated via the RS-232 serial port to Pentium Pro processor and generated a digital pulse to control the precision spraying system. The control algorithm was implemented in C language. P. E. Cruvinel and E. R. Minatel [12] developed a rapid method for automated classification of oranges in living trees by size. The control algorithm was implemented in C language on a PC with Windows environment.

3. METHODOLOGY

3.1 Experimental Setup

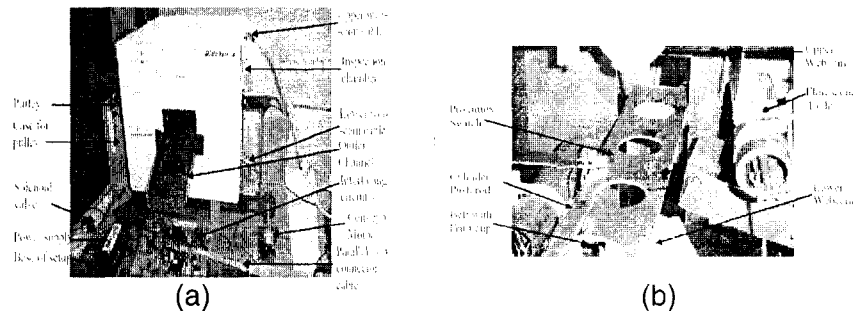


Figure : 1 : Experimental setup (a) Exterior view (b) Interior view

The system, shown in figure 1, consists two low cost web cams made from Logitech with a video capture of 640 x 480 pixels and frame rate of 30 frames per second. One web cam is placed at the top of the inspection chamber and the other at the bottom of the chamber to capture the upper and lower part images of the tomato respectively. A belt conveyor system is designed to carry the tomatoes in the acquisition areas. Images are captured, processed and decision is made by the algorithms developed by using Matlab 7.0. The defected tomatoes are sorted by pushrod-cylinder system, which is operated by solenoid valve. The conveyor motor and the solenoid valve are switched by pulses from parallel port programmed by data acquisition toolbox of Matlab.

3.2 Defect Detection Algorithm:

For defect detection, Green house grown tomatoes are taken as samples. Two types of defects are selected for sorting, which is very common to all kinds of tomatoes. These are 1. Blossom End Rot (BER) and 2. Cracks. Other feature like Calyxes is also selected to distinguish these from defects. In image processing algorithm color image of the tomato is processed by extracting R, G and H matrix and applying a threshold. The algorithm uses bwlabel function to label the segmented images based on connected component. The decision sorting has been developed by decision logic using selected criteria and threshold values which is applied on images after processing. This approach is rule based, and it has been found that it can clearly detect the BER from good and calyxes but is less efficient in Crack-Calyx identification. So we have also applied the neural network approach to solve this problem.

3.3 Controlling Approach

To design the controlling system parallel port is programmed by using Matlab. The parallel port consists of eight data lines, four control lines, five status lines, and eight ground lines. Figure 2 shows the pin outs of a standard parallel port. In normal usage, the lines are controlled by the host computer software and the peripheral device following a protocol such as IEEE Standard 1284-1994. The protocol defines procedures for transferring data such as handshaking, returning status information, and so on.

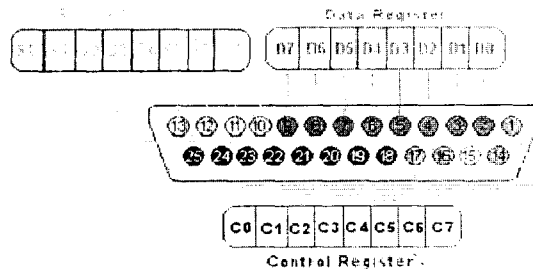


Figure 2: Pin outs of standard parallel port

However, the toolbox uses the parallel port as a basic digital I/O device, and no protocol is needed. Therefore, we can use the port to input and output digital values just as we would with a typical DIO subsystem.

The toolbox groups the 17 no ground lines into three separate ports. The port IDs and the associated pin numbers are given in the table 1 below [13].

Table 1: Pin assignment of a standard parallel port

Port ID	Pins	Descriptions
0	2-9	Eight I/O lines, with pin 9 being the most significant bit (MSB)
1	10-13,15	Five input lines used for status
2	1,14,16,17	Four I/O lines used for control

3.4 Main Components of the Control System

Main components of the control system are as follows:

Proximity Sensor

A simple two-way contact switch is used for detection of the tomato. The switch has internal connection such that when it is pressed its normally close pin becomes open and normally open pin becomes closed. It has another pin that is common. When the tomato touches the proximity switch, it closes and it sends an input pulse through the interfacing circuitry to the status pin (13) of the parallel port.

Interfacing Circuitry

Figure 3 shows the interfacing circuitry for controlling the Machine Vision System. The Main components of interfacing circuitry are as follows:

Buffer circuit for processing input pulse

The input pulse is passed through an Octal Buffer or Line Driver IC 74LS244 that is designed to make Hysteresis at Inputs to Improve Noise Margins, protect the parallel port with Input Clamp Diodes that limit High-Speed Termination Effects [14].

Parallel port (DB-25 pin female port) connector:

A 25 pin D shape connector is used to interface the parallel port of the PC. 8 and 9 pin of it is used to control the actuators such as conveyor motor and solenoid valve and 13 pin is used to receive the input pulse from proximity sensor.

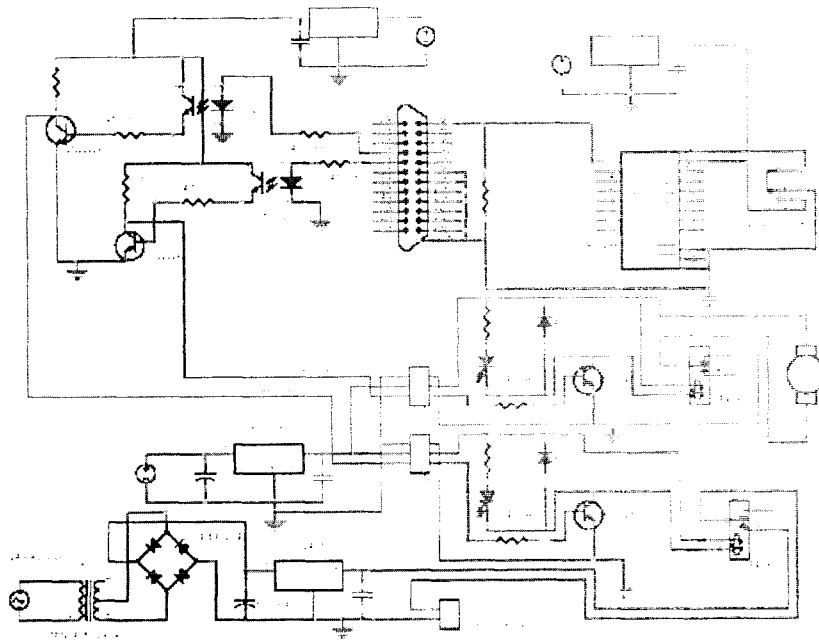


Figure 3: Interfacing circuitry for controlling Machine Vision System

Driver circuit for the actuators

A driver circuit is designed by using opto-coupler for isolating the power supplies between the load and the Computer. This will protect the PC from back current due to the loads. Transistors supply more current to the loads.

Control relay module

This module circuit is used to drive the loads by getting control pulse from the driving circuits by switching the relays.

Power supplies

Different power supplies are used to give power to the different loads. Power supplies are made with regulated IC (7805, 7812, and 7824) so that uniform loading can be possible.

Controller

No micro controller is used for controlling the actuators. This system uses a High Speed Pentium4 PC with 512MB of RAM so that it can process the image data as well as send pulse to the motor and solenoid to control according to the control algorithms.

3.5 Control Algorithms

The control algorithm is written by using data acquisition toolbox of Matlab 7.0. The algorithm consists of configuring the parallel port and selecting its status pin 13 to sense the input and 8 and 9 data pins to control the actuators. The proximity switch is connected with pin 13 so if the switch closes it becomes high and it is read by the control algorithm and it makes the 8 pin high so that the motor stops at that instant and 9 pin high for making idle of the solenoid and image acquisition starts and followed by a simulation for defect detection and if it finds any defects it will make the 9 pin low to actuate the solenoid valve. If there is no defect the control algorithm makes both the 8 and 9 pins as high so that motor conveys the good tomato and solenoid remains at off position. Figure 4 shows the control algorithm using Parallel port.

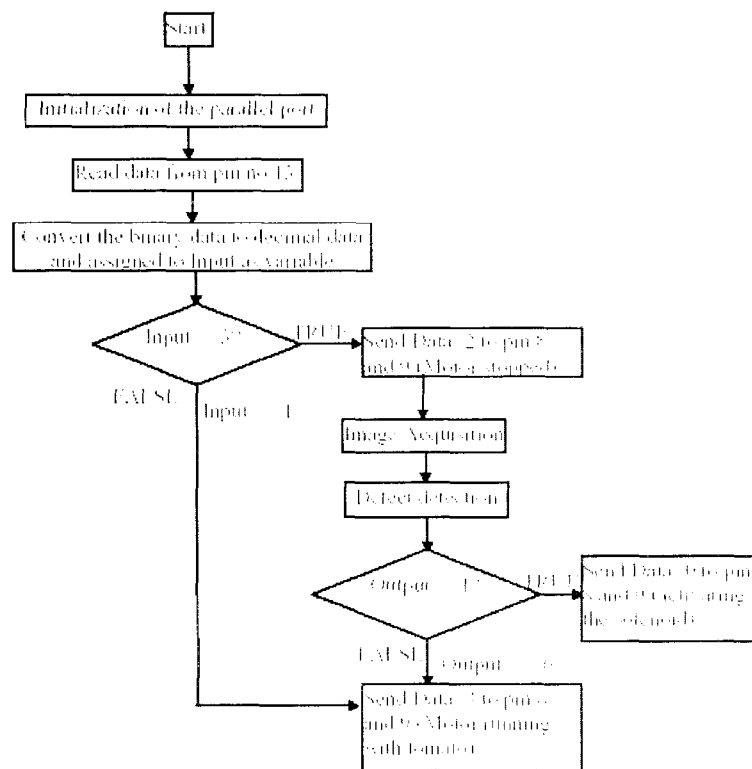


Figure 4 : Control Algorithm

4. DATA ANALYSIS:

4.1 Inspection and Control Results:

The entire control architecture is based on Pentium 4 processor with 512 MB of RAM with 866 MHz Clock speed. The image data is processed by the Microprocessor and parallel port receives the data through a proximity sensor. The process is implemented and simulated through Matlab 7.0. After immediate sense of the tomato, the data is sent through the parallel port for processing and after decision making it sends signals to the same port for control.

With the oscilloscope, the time elapsed between the two events has been measured with an accuracy of 0.01 ms. Table 2 shows the maximum and minimum times consumed in each process.

Table 2: Measurement of the time consumed by the inspection and control process

Task	Minimum time (ms)	Maximum time (ms)	Average time (ms)
Sensing the tomato at proximity switch	10	14	12
Defect analysis and recognition (microprocessor)	90	170	114
Application time (start of motor or actuation of solenoid valve)	90	170	114
Inspection speed (tomato/sec)	8	5	6
Sorting speed (tomato/sec)	6	3	5

4.2 Defect Detection Results:

For detection purposes 160 samples of each class namely Blossom End Rot (BER), Crack, Calyx and Good tomatoes are presented to the machine vision system. The results are tabulated in table 3. The same results are shown graphically in Figure 5.

Table 3: Defect detection accuracy results

Class	Type	No. of tomatoes detected	No. of misdetection	Detection accuracy
BER	Defect	160	03	98.12%
CRACK	Defect	160	87	45.62%
CALYX	Good	160	45	71.82%
GOOD	Good	160	142	88.75%

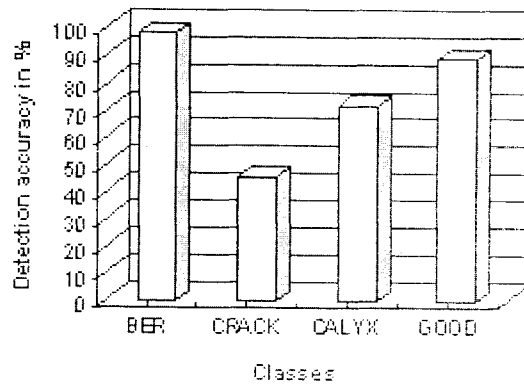


Figure 5: Detection accuracies for the various classes

6. CONCLUSION

Developing the control approach using Matlab gives us enormous flexibility and enhanced feature for control of the Machine Vision system. Without changing Operating System mode we have been able to modify our codes for execution of the system. The sorting speed of the defective tomatoes has been found 5 tomatoes/sec, which is an acceptable for automation of fruit sorting. In comparing with C based control it has been found sufficient fast to achieve our goal. The difficulty with C language for modern operating system that it needs special DLL files to run and the most difficult part of it is placing the DLL at appropriate position in the program. For this purpose we need special knowledge of the use of the DLL files. And if the operating system changes we cannot modify our program so easily compared with Matlab. Matlab supports to use data acquisition cards manufactured by several renowned companies like National Instruments, Measurement Computing, Agilent Technologies, and sound card hardware from different companies. The whole machine vision system is based on Matlab so the different subsystems are interlinked and communicate easily without interpreter. The system is compact, low cost, easy to operate, easy to install and easy to modify to other fruit sorting system. The system don't have a fruit loading and unloading unit so addition of such an unit can enhance its feature and can be used in a real world machine vision system.

REFERENCES

- [01] Rokunuzzaman, M., Akhter, M.S. and Afzulpurkar, N.V. "Automatic Controlled Defect Sorter for Tomatoes based on Machine Vision", a paper published in the Proceedings of the 4th Asian Conference on Industrial Automation and Robotics, 11-13, May, 2005, Thailand, pp. 65-68.
- [02] <http://www.logix4u.net/parallelport1.htm> (1 of 5) retrieved on 23/2/2005
- [03] Axelson, Jan., Parallel Port Complete, Programming, Interfacing, & Using the PC's Parallel Printer Port, 1996, ISBN 0-9650819-1-5, pp.1- 3.
- [04] Engdahl, Tomi., Parallel port interfacing made easy: Simple circuits and programs to show how to use PC parallel port output capabilities, Published by ELH Communications Ltd, retrieved from http://www.epanorama.net/circuits/parallel_output.html on 20/3/2005.
- [05] Emulating the Centronics Protocol in MATLAB, article, retrieved from <http://www.mathworks.com/matlabcentral> on 25/3/2005.
- [06] Shahin, M. A. and Symons, S. J., "Instrumental Colour and Size Grading of Pulse Grains", a paper published in the proceedings of the World Congress of Computers in Agriculture and Natural Resources, 13-15, March, 2002, Iguacu Falls, Brazil, pp.107-113.
- [07] Aleixos, N., Blasco, J., Navarro'n, F., and Molto, E., "Multispectral inspection of citrus in real-time using machine vision and digital signal processors", Computers and Electronics in Agriculture, Vol. 33, pp.121–137, 2002.
- [08] Wen, Zhigang., and Tao, Yang, "Building a rule-based machine-vision system for defect inspection on apple sorting and packing lines", Expert Systems with Applications, Vol.16, pp.307–313, 1999.
- [09] Blasco, J., Aleixos, N., and Molto, E., "Machine Vision System for Automatic Quality Grading of Fruit", Biosystems Engineering, Vol. 85 (4), pp.415–423, 2003.

- [10] Laykin, S., Edan, Y., and Alchanatis, V., "Development of a Quality Sorting Machine using Vision and Impact", ASAE Paper No. 99-3144, ASAE, St. Joseph MI-49085, 1999.
- [11] Lee, W.S., Slaughter, D.C., and Giles, D.K., "Robotic Weed Control Systems for Tomatoes", Precision Agriculture, Vol.1, pp.95-113, 1999.
- [12] Cruvinel, P. E., and Minatel, E. R., "Image Processing in Automated Pattern Classification of Oranges", a paper published in the Proceedings of the World Congress of Computers in Agriculture and Natural Resources, 13-15, March, 2002, Iguacu Falls, Brazil, pp.56-61.
- [13] Line and Port Characteristics, Data Acquisition Toolbox documentation, Matlab, version 7.0, 2004.
- [14] Datasheet of SN54/74LS244, octal buffer with 3-state outputs, from Motorola, Inc.