# Quality management of agricultural products



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**TITLE**
# QUALITY MANAGEMENT OF AGRICULTURAL PRODUCTS

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## ABSTRACT

The quality of the agricultural products can essentially be benefited by the advancements in the data acquisition and control systems' technology. In particular, the inspection process of fruits, such as the oranges, can be more effective using the image recognition techniques.
During the packing process, the fruits have to be graded in terms of their size and color respectively. This function can be performed automatically by an information system. In this way, various parameters such as the size and the color of the fruits can be controlled by a camera equipped computer which runs a specific software application for image recognition.
Several quality algorithms for inspection are allowed and easily implemented by the computer system. Thus, the modern technology provides the solution for a quality management of the agricultural products that supports the time reduction, the flexibility of parameters inspection, the lack of human inspection errors, and many other factors which influence the effectiveness and the efficiency of the agricultural products inspection processes.

## KEYWORDS

**Keywords:** Machine vision, image recognition, data acquisition software techniques, fruits and vegetables inspection, food quality inspection and control.

## HUMAN VS MACHINE

One of the most significant advances made in automation technology is that which provides detailed analysis of a monitored object, rather than simply detecting its presence. Being able to define an object's shape, colour and depth allows far greater control over standard production methods.

'Faster, more robust, greater accuracy, cost effective' - these are the more significant aspects driving development and innovation within the sensor and control markets. Machine vision designers have always provided solutions for customers demanding some combination of these criteria. Unfortunately, there has always been a trade-off - the greater the accuracy, the slower the speed.

But now, with the impressive array of opto-electronic devices currently available to the marketplace, the trade-off is diminishing. High performance and low cost are no longer opposing factors. This article takes a look at some of the need-to-know aspects.

The human brain serves as a very efficient image processor. Millions of years of evolution have given us the ability to analyse visual information far in excess of any modern computer. But for all that visual ability, we still make mistakes. What may seem at a glance to be an acceptable defect to one person, may be a critical defect to another. Although a machine vision system requires a simplification of the visual problem, as long as it is programmed correctly, it won't make mistakes. Speed, accuracy and repeatability are order of the day in production runs and what humans can't do without time and tools, a machine vision system can do thousands of times over. It never tires and always works.

To summarise, if the production requires fast, well-defined, precise and repetitive tasks, the machine vision is the solution. However, if flexibility, low speed and low accuracy are the requirements, the human eye is the option to stick with.

In the automation of hothouse tomatoes and fruit grading, the human hand and eye are extremely efficient at inspection tasks. Without any training, we can evaluate the produce and determine if it is suitable for consumption. The two most significant factors affecting the overall efficiency are speed and boredom. In a machine vision system, the produce has to be dealt with in a more precise manner - all sides must be inspected via mechanical rotation and then the system has to be programmed to determine the states of good or bad.

Colour is the primary indicator of grade and is particularly relevant for tomatoes. We know that red is ripe and green is unripe. But what of the 'shades' in between? This is very difficult to assess without complex adaptive algorithms, but the advances made in sensor technology, neural networks and fuzzy logic help make the task simpler for hardware and software alike.

Traditionally done by hand, fruit sorting and grading is a very labor-intensive aspect of the fruit processing industry. Labour shortages and a lack of overall consistency in the process resulted in a search for automated solutions. Visual quality grading remains one of the most difficult processes to automate in fruit and vegetable processing as well as in other areas of the food processing industry. Color is a key parameter in the implementation of many quality decisions, and thus a low-cost integrated color vision system, which includes the image acquisition and processing, is necessary for tackling many of the existing problems in the food processing industry.

Machine vision has long been seen as a potential solution for various automated visual quality grading processes. The current state of machine vision relies on complicated software algorithms and requires relatively high system costs to meet the speed requirements. The development of automated systems for parts sorting and segmentation has been implemented and is now being utilized in many food processing facilities. General systems for quality grading, defect detection, or intelligent machine controls have not yet realized these successes.

This paper focuses on a video-grading machine capable of sorting individual oranges.

## DIFFICULTIES AND PROBLEMS

In the real world, most orange packers still inspect and grade fruit manually. Economic and technical considerations limit machine vision solutions at the component level. Thus, vision finds application only in large packing operations that are able to afford the installation of a completely new, fully integrated production line.

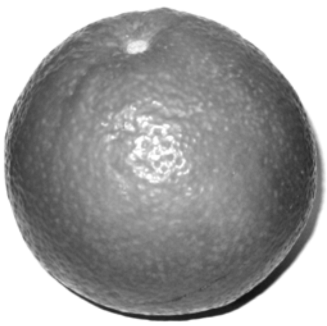
The cameras must perform primary grading to ensure that no more than a given percent of an orange's surface is damaged or discolored, and that small punctures are not mistaken for the stem area and vice versa. The stem area takes up less than 2 percent of the surface.

The two most important considerations in applying vision to orange inspection are the speed of the conveyor and what types of defect the system needs to detect. Final component selection is driven by price, service, and hardware and software performance.

For the discoloration process, we assume that the visual image obtained will be sufficient to detect this error. The greater challenge is high-speed detection of punctures, which may be small but deep and can be mistaken for the stem area.

Successful blemish sorting of oranges comes down to solving one big problem: the correct classification of the stem and navel. Like surface blemishes and bruises, punctures compromise an orange's shelf life and overall quality. But the minimal surface area these wounds can occupy makes automated detection difficult.

Photo 1 shows a perfect orange with the stem on the top side.



Ph1. A perfect orange

Complete automation of the visual inspection and sorting of oranges promises significant benefits for commercial producers in terms of reduced labour costs, reduced time to market and improved quality. However, in order to be commercially viable, a machine must be capable of recognising and sorting many individual oranges per second on a continual basis, imposing very high demands on the transportation, image acquisition and recognition systems.

## DESIGN APPROACHES

To develop an automatic grading system based on video capture techniques there are several approaches.

**a)** Capturing thousands of images and classifying the marks using computer programs. Next step is to look at each picture to corroborate the accuracy of the software to refine a system that correctly classifies the stem about 90 percent of the time.

**b)** By combining the latest in neural parallel hardware with digital signal processors and virtual machine language programming tools, the PREFER consortium are developing a machine which aims to sort at least four tons of oranges per hour. The commercial implications of such a machine for the fruit and vegetables industry are enormous. The grading hardware consists of a mechanism that conveys individual oranges through an illuminated inspection chamber, in which six independent and simultaneous images are acquired of the surface of an orange. Stem detection is the most demanding computation based on these images, and therefore uses new neural parallel hardware (L-Neuro 2.3)

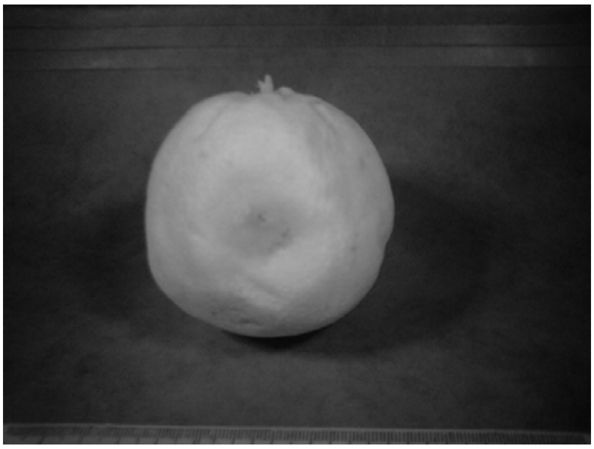
**c)** Georgia Tech research engineers in partnership with Durand-Wayland, a LaGrange, Georgia-based, agricultural processing equipment manufacturer, have tackled the task of designing a machine vision-based inspection and grading system to evaluate grapefruit. The system uses an array of low-cost color USB cameras to identify blemishes, defects, and color inconsistencies at a throughput rate of 600 fruit per minute. The ability of the system to accurately inspect the entire surface of each fruit while accommodating the natural variation between fruit is a significant breakthrough. The system consists of two imaging cells that are placed on a grapefruit conveyor line. One imaging cell captures the top half of the fruit, while the other captures the bottom half of the fruit. This eliminates the need to mechanically manipulate the fruit in any way. There are also no orientation constraints since the entire fruit is being captured. The captured images of the fruit are processed in real time. The current system identifies green spots, blush, dark and light scaring, and melanose. It also has the capability of determining the shape and size of the fruit as a grading criteria. The end user has the ability to define different end grades based on the percentage coverage of these defects. The grading system was designed to interface with a kickoff device that automatically channels the various grades of fruit to the appropriate locations for packing. Keys to the success of this system are its ability to accommodate the nonuniform nature of the product and guarantee complete and consistent evaluation of the fruit. This requires high-speed adaptive processing algorithms that merge the data collected from multiple images into one final assessment of each fruit. All of this is made possible by the use of low-cost cameras that help to contain the costs and make the system financially viable.

## IMPLEMENTATION USING NI VISION BUILDER AND IMAQ

Seeking for a solution that could be both economic and effective the approach adopted by the authors was to use monochrome images under red light to increase contrast and highlight small flaws such as punctures. In Ph.2 and Ph4 there are orange images with red illumination. In Ph3 and Ph.4 the same images have been increased in contrast. The result obviously helps the analysis of the defected oranges.

For the tests a monochrome camera was used. Alternatively, a low cost USB color camer could be also used. Either the monochrome or the color cameras are producing images to feed the personal computer that runs particular image analysis software. For the purposes of the test the National Instrument's Vision Builder and IMAQ (image acquisition) were adopted.

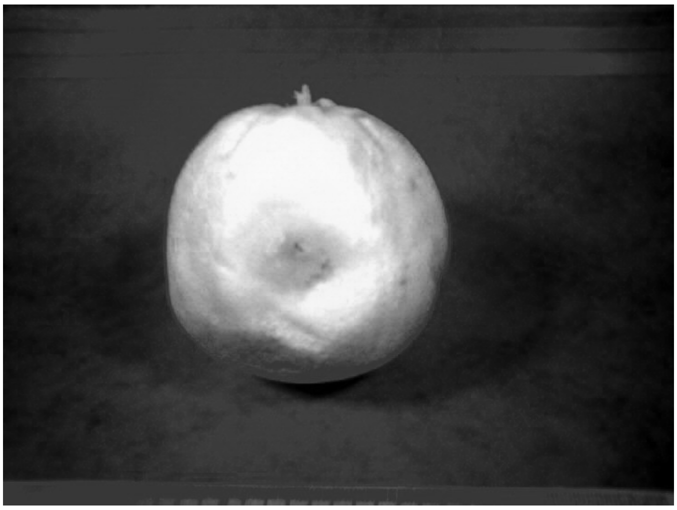
Using NI Vision Builder for Automated Inspection, you can easily configure and benchmark a sequence of visual inspection steps and deploy the machine vision inspection system in an automated environment. Not only is it possible to perform powerful visual inspection tasks, but it also makes pass/fail decisions based on the results of individual tasks. Additionally, it is very easy to communicate with external devices using serial lines and discrete I/Os.



Ph2. Defected orange illuminated with red light

As part of the test solution, NI Vision Builder for Automated Inspection performs a variety of functions, including processing, analysis, decision-making, presentation, and code generation for LabVIEW.

Image processing is typically the first function an engineer applies to an image before analysis. The new NI software includes many processing functions to filter noise, extract color planes, and perform thresholds.

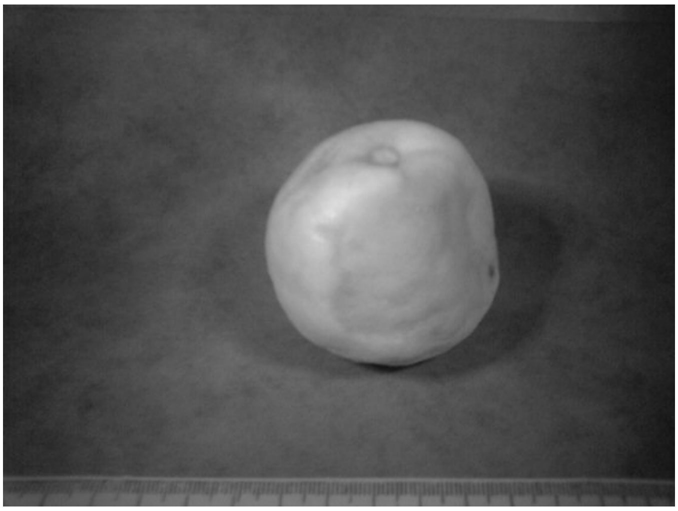


Ph3. Defected orange illuminated with red light and more contrast

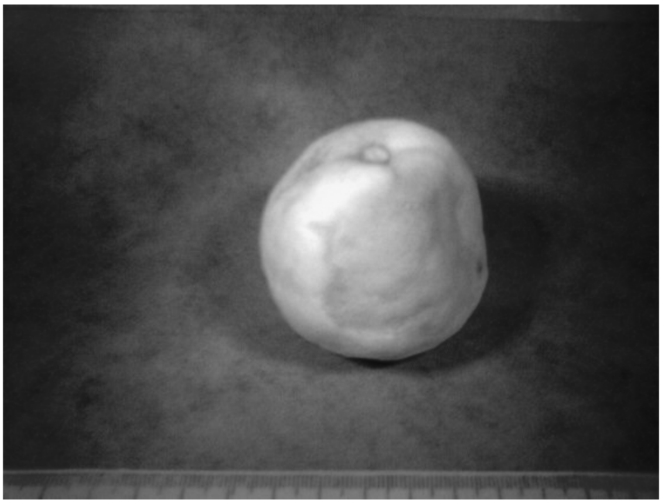
In many machine vision applications, the object under inspection appears shifted or rotated within the image. For reliable inspection, both the regions of interest and the inspection measurements need to shift and rotate in conjunction with the object under inspection. For the regions of interest to move in relation to the object, you need to set a coordinate system relative to a significant and original feature of the object under inspection.

NI Vision Builder for Automated Inspection includes an intuitive coordinate system function, so you can obtain measurement data from a previous inspection task, build a coordinate system, and transfer the new system information to all subsequent inspection measurements. The regions of interest and the inspection measurements then shift and rotate with the object under inspection, resulting in accurate and repeatable measurements.

During processing, you must obtain inspection data from camera sensors, which always return the data in pixels. Unfortunately, you need to perform inspection measurements in real-world units, such as millimeters or inches. Using the calibration tools included with NI Vision Builder for Automated Inspection, you can calibrate your data so all measurements are computed in the appropriate units. Also, you can eliminate lens and perspective distortion using an NIST-certified calibration grid and the advanced calibration algorithms in the new machine vision software.



Ph4. Defected orange illuminated with red light



Ph5. Defected illuminated with red light and more contrast

After image processing, you are ready to analyze. NI Vision Builder for Automated Inspection includes many analysis functions to solve your application challenges. You can use caliper tools to measure distances in your image or use the advanced geometric tools to perform routines such as curve fitting and angle measurements.

You also need histograms to determine if specific components of a part are present. Histograms return average pixel intensity values for a given region of interest. If the part is present, the pixel values are high, but if the part is not present, the pixel values are low. Morphology functions find and classify specific particles or objects in your image. You can access more than 50 functions for classifying particles such as size, location, circularity, and quantity.

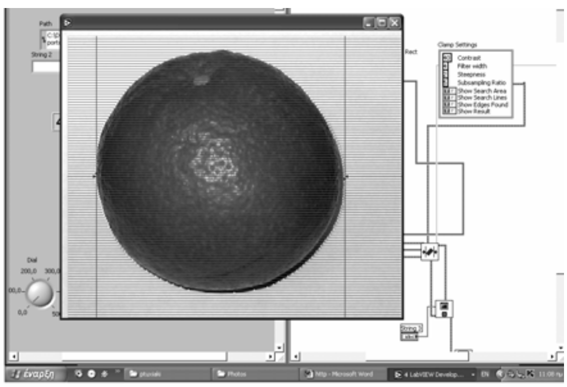
Further, many machine vision applications require searching an image for a specific pattern or fiducial. NI Vision Builder for Automated Inspection includes National Instruments patented pattern matching algorithms to quickly locate patterns with very high accuracy. The search algorithm is resistant to noise, blurring, rotation, lighting changes, and partial occlusion.

On the manufacturing line, the most important data is whether a part passes or fails the inspection. With the advanced decision-making capabilities of NI Vision Builder for Automated Inspection, you can define pass/fail criteria and classify parts. Also, you can set limits for each individual inspection step and use the intuitive decision-making interface to create complex decision expressions for the entire system, incorporating pass/fail criteria from multiple steps.

Time constraints on the factory floor require that you complete inspection tasks in a predetermined amount of time. With the built-in performance meter, you can see how quickly the inspection steps execute. When you are satisfied with the results and the processing time of the inspection, you can quickly deploy your application.

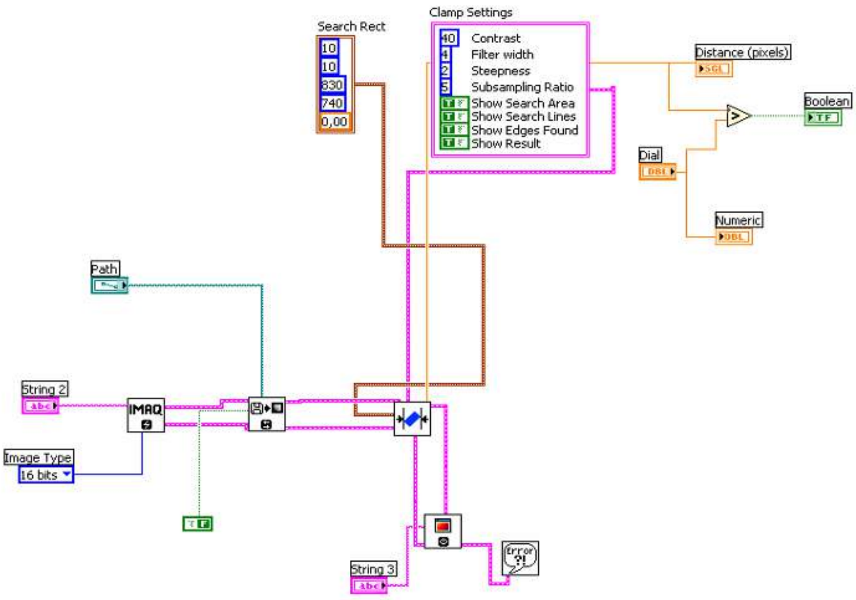
When your application requires the complexity of an application development environment, you can convert the NI Vision Builder for Automated Inspection script to LabVIEW and IMAQ Vision code. You can develop custom user interfaces, as well as integrate motion control, process control, and data acquisition in LabVIEW.

In the following photos, Ph6, Ph.7 and Ph8, it is illustrated the code developed for size and defects grading using LabView from National Instruments.



Ph6. Grading using NI


Ph8. Color control using NI




Ph7. Grading Block-Diagram using NI's LabVIEW and IMAQ

## CONCLUSIONS

Machine vision can provide an economical and efficient way to do inspections that are precise, repetitive and high speed. Human vision is more capable and certainly easier to 'program', however, we are slow, imprecise and unreliable. Because there are limitations to machine vision, implementing the correct inspection method must be considered initially to obtain the final result. The knowledge of experienced machine vision systems integrators is essential for correct application. Ultimately, with good planning, expert knowledge and the right tools, success of the machine vision system is guaranteed.

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