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Abstract: Mechanical fruit grading and automatic fruit grading have been detailed in this paper. The studies and applications of mechanical fruit grading, and computer visual and automatic fruit grading were also particularized. Computer vision technology for detecting fruit size, color, bruise and surface defects and evaluation of fruit overall quality were discussed. The primary problems and development in the future in application of automatic fruit grading in China were pointed out in the end.

Keywords: fruit, grading, mechanization, automatization

1. INTRODUCTION

Fruit commercialization is the main purpose of its grading. Fruit in the same tree differ in quality such as feature, flavour because their growth was effected by many environmental factors. Especially, fruit from different orchards differ significantly in size and quality. Grading may not only standardize fruit product but also promote management of the fruit tree in orchard and product quality (Haisheng Gao, 2003; Lite Li et al., 2003).

Fruit and vegetable are very difficult to grade exactly and rapidly because of their significant difference in feature such as size, shape and color as a result of changeable conditions of nature environment and manual factors. Grading of fruit and vegetable was performed primarily by visual inspecting

in many countries. Manual grading is lack of objectivity, accuracy and has lower efficiency because there is individual difference in visual inspecting which is affected by human healthy condition, psychological condition, lightness, fatigue and so on. But levels of mechanical and automatic grading of fruit and vegetable go higher and higher with the enhancement of mechanization, automatization and application of computer technology.

2. MECHANICAL FRUIT GRADING

Mechanical fruit graders are classified by their working principles as size grader, weight grader, fruit color grader and fruit color and weight grader which classifies fruit by their size and color.

Fruit grading by their size and color is the advanced technology of the post-harvest fruit handling nowadays in the world. Its working principle is a combination of automatic size grading and color grading. At first, size grading of fruit is done on conveyer belt with changeable apertures. Fruit down from the belt are irradiated by lamps under conveyer belt and yield reflex. Then the reflex signal was passed to computer and different grades of fruit such as the whole green, the half-green and half-red and the red under every conveyer belt were obtained according to different reflex signals. Finally, the graded fruit were transported by different conveyer belts. The capacity of the apple grading product line might reach 15 to 20 tons per hour (Haisheng Gao et al., 2002, 2003; Miller B. K., 1989).

The near-infrared (NIR) transmittance spectrum of peach from different areas in wavelength range from 730 to 900 nm was studied to estimate peach ripeness in terms of sugar content and firmness. The accuracy of the estimation reached 82.5% (Carlomagno et al. 2004).

The grading of “Jonagold” apple was studied at the most effective wavelength at spectral range from visible light to near infrared light (450nm to 1050nm) (Kleynen et al., 2003). Apple image information was gathered using CCD (Charge Coupled Device) and apple were sorted on the basis of their sizes, color and defects on surface. The results showed the high efficiency of apple grading was obtained at wavelengths of 450, 500, 750 and 800nm.

A grading criterion for cucumber was put forwards (Zengchan Zhao et al., 2001, 2003). Picking robots and conveyors based on machine vision system were developed and a set of hardware and software system for cucumber grading was designed.

3. COMPUTER VISION AND AUTOMATIC GRADING OF FRUIT

Computer vision system can simulate human vision to perceive the three-dimensional feature of spatial objects and has partial function of human brain. The system will transfer, translate, abstract, and identify the perceived information, and consequently work out a decision and then send a command to carry out expectant task. The simple computer vision system consists of illuminating chamber, CCD camera, image collecting card and computer. The chamber maintains an optimal work condition for the camera, namely, keeping a symmetrical and identical illumination in CCD vision area. CCD camera is an image sensor for capturing image. The image collecting card abstracts the image and translate video signal into digital image signal. The computer handles and identifies the digital signal to work out a conclusion and explain.

3.1 Detection of the fruit size

Fruit images can be captured by computer vision system. And then the detection of their edge was executed. The measuring direction of the fruit size would be oriented according to the fruit symmetry, and then the fruit size would be measured. The method of detecting the fruit edge is very suitable for processing blurry image. The method has not only high processing speed, but also does not need the further process such as fining and sequencing. The fruit axis is selected by its symmetry in detecting of the fruit axis direction, which has good universality and higher detecting accuracy. In two groups of fruit experiments, the correctness of detecting of axis direction reaches 94.4% and the maximum absolute error of measuring the fruit size is 3 mm. It can meet producing need and the axis direction detected by this method agreed with the manual one. The method accords with international standard (Bin Fen, 2003).

On the basis of overall analysis of the fruit shape, the shape was described with 6 feature parameters, namely, radius index, continuity index, curvature index, symmetry of radius index, symmetry of continuity index and symmetry of curvature index. The reference shape method was firstly employed in the analysis of apple shape feature and the artificial neural network was used in the evaluation and sorting of the fruit shape. The results showed that the average consistency between computer vision grading and manual grading is over 93% in terms of obtained feature parameters and the fruit shape analysis technology (Jing Zhao et al., 2001).

3.2 Detection of the fruit color

Color is extrinsic reflection of intrinsic quality of fruit and vegetable. Consequently, it becomes an important study object and a basis of grading in computer vision system. Some color models should be adopted for evaluating color feature of the fruit surface in color discrimination (Dongjian He et al., 1998). Many special color models had been set up in some relevant studies. RGB and HIS model were often used in computer vision system to describe color, which is more similar to the manner of human vision. The HIS model includes three elements: hue, saturation and intensity. The color threshold values for discriminating different color grades were chosen according to the findings of color study and relative criteria. The accumulative frequency relative to the threshold value was obtained and then color grade would be done. HIS color system is very suitable for color evaluating and image processing. Meanwhile, the correctness of grading was more than 90% if indicating color feature with hue histogram and multi-variables identifying technology were used in detecting color of potato and apple (Shuwen Wang et al., 2001).

Tomatoes were classified into six maturity stages by computer vision system according to the USDA standard classification: Green, Breakers, Turning, Pink, Light Red, and Red (Choi et al., 1995). The classification results agreed with manual grading in 77% of the tested tomatoes and all samples were classified within one maturity stage difference. The grading correctness of bell peppers was 96% using computer vision system to grade fresh fruit and vegetable (Shearer et al., 1990).

3.3 Detection of the fruit bruise and defects on its surface

The bruise and surface defects of fruit have severe effect on the intrinsic and extrinsic quality of fruit. Removing bruised or surface defective fruit not only is requirement of grading, high quality high price, but also is an important process for preventing fruit from rotting and deteriorating. Detecting bruise and defects of fruit is yet an obstacle to implementing the real-time grading of fruit.

Some findings showed that there is a different spectral reflectivity in the range of visible light for the bruised or/and the defective region on fruit surface compared to the normal one. Hereby, surface defects can be detected in wavelength range of visible light. In addition, fruit bruises often occurred at random in the process of picking, loading, unloading, and transportation. Grade criteria in terms of the number of the fruit bruises and the area of each bruise were set up in some countries. So they become criteria for grading in a computer vision system.

There was a color difference in the joint region of the defective and non-defective regions of Huanghua pear (Yibin Ying et al., 1999). The light values of R (red) and G (green) were used to distinguish the defective region from the non-defective region. The whole defective region was found by means of region growing method. Finally, the area of the defective region was calculated. The automatic detecting of pear bruise was studied (Tailin Zhang et al., 1999). The bruise signal was separated from background image and pear normal tissue image by employing many image pretreatment techniques. And then different bruised regions were separated each other with the aid of denoting different bruised regions with different gray values. A detecting criterion was set up according to the national pear grading standard in order to use computer detecting system in practice. A mathematic model for calculating bruise area was put forward according to pear shape and the characteristics of bruise. Measuring relative errors can be controlled with in 10%.

3.4 Overall quality evaluation

The fruit quality is a concept of overall quality. Bigger but off-color fruit and smaller but colourful fruit were often found in production. The fruit feature such as shape, size, and color was dependent on the inherent character of its variety. Fruit will have good feature if they normally grow in suitable areas and are harvested at the ripe time and vice versa. In a word, shape, size, color and bruise of fruit altogether decide its quality. The purpose of grading is a quality classification. The index measuring is only a means.

A real-time fruit sorting mechanism and its controller, which are the key parts of a robot for the fruit quality inspecting and sorting, were developed in Zhejiang University. The sorting mechanism consists of a feeding and upturning system, a computer vision inspecting system, and a grading system. Double cone-shaped roller for the fruit feeding and upturning keeps the fruit forward feeding at a certain speed and rotating at random on a parallel axis to make the whole surface of fruit being detected by inspecting system and get adequate images. The computer vision inspecting system processes these images to encode an order about the grade of every fruit and its real position in the sorting mechanism and then pass it to the grading system through the controller of inspecting system. Fruit grading will be done (Yibin Ying et al., 2004).

A type of controller for the fruit synchronous tracking and automatic grading was developed (Yonglin Huang et al., 2002). Results of image processing were sent to a parallel port of a computer from a shift register.

Certain pulse signals from sensors were taken as the shift signals, and the positions of processing results in shift register keep the same pace with that of every fruit on the grading line. In this way, the synchronous tracking of fruit was realized. Meanwhile, an effective method to control the pulse distribution and correlative action of step motors, which were used to drive the grading mechanism, was also developed.

4. CONCLUSION

The manufacture of the fruit grading equipments in China is still limited in the field of mechanical grading equipments which mainly include size grader and weight grader at present. The mechanical and automatic graders are mainly imported and aren't used widely. Model 6GF-1.0 size grader for fruit, developed in China nowadays, was designed by the advanced grading principle according to the clearance between roller and belt. The working principle is: (1) the grading roller rotates at uniform velocity; (2) the conveyer belt moves in line; (3) fruit will fall down from the clearance into their receiver if their sizes are less than the clearance; (4) fruit grading will be done. Model GXJ-W series horizontal sorters for fruit and vegetable were manufactured in Xixia Maoyuan Machinery & Equipment Factory in Shandong province, which are fit for sorting spheroidal fruit or vegetable (e.g. pear, apple, persimmon, peach, lemon, guava, tomato, orange and potato). They are high efficiency sorters (Huan Liu, 2006).

The study on dynamic properties of agricultural materials was not put a premium in China because of the limitation of basic techniques. The development of automatic grading equipments in China is still in the stage of laboratory testing. Therefore, China should keep pace with international, newest developments in these fields, make the best of findings acquired abroad, and seek after new theories and methods to greatly develop new-type automatic grading equipments and promote the grading handling capacity to a great extent.

The great progress in post-harvest fruit grading technology will occur with developments of computer technology, mechanical technology and electronic technology, and their combination. The synchronous grading device with functions of detecting the fruit feature and evaluating its quality is hopeful to be manufactured in the future. Different species of fruit need different mechanical performance in industry of the fruit tree in China, for example, anti-bruising function for white pear, color detecting for yellow pear, shape detecting for particular shape pear (e.g. 'Ya' pear, 'Kuerle' sweet pear), detecting blackheart for blackheart-suffering pear.

In conclusion, commercialization of the post-harvest fruit and vegetable is a systems engineering. It consists of series of correlative and matched technologies. It is an integration of technologies in many different fields.

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