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Design of Computerized Combination Balance with Automatic Grading Technology

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Abstract: In the area of commodity circulation and food packaging, the development and application of computerized combination balance improve the production efficiency and weighing accuracy of the enterprises, and promote the automation development in packaging industry. This paper designs a kind of new computerized combination balance with automatic grading technology based on the principle and process of the traditional computerized combination balance. A case study of apple string bag packing is given, and in this case, the combination packing algorithm is designed, and simulation is done by MATLAB. The result shows that the computerized combination balance designed in this paper can be applied to fruit grading and combination packaging effectively.

Keywords Computer image recognition; Grading technology; Computerized combination balance

INTRODUCTION

Computerized combination balance is a kind of electronic weighing apparatus which uses the combination weighing principle, and can weigh fast and accurately. With the rapid development of electronic and computer technique, computerized combination balance has been applied in commodity circulation widely. At present, computerized combination balance mainly uses the method of multi-scales combination. The weighing precision has been improved constantly, and the weighing range has expanded from regular shape commodity to irregular shape commodity (such as candy, chips, etc.) on the premise of keeping the weighing speed. Many commodities need to be graded before packaging, for example, some fruit need to be graded according to size, color and other indicators. At present, fruit grading is almost conducted manually in China, and automatic grading equipment has not worked on a large scale. If fruit can be graded through computer image recognition, and packaged by computerized combination balance, it will save manpower greatly, improve the production efficiency, and reduce the damage to fruit during the process of circulation and packaging.

Computerized combination balance based on combination weighing technology was designed and manufactured in the UK in the 1970s. And then it was developed and popularized in Japan, Germany, the United States, France and several other developed countries[Wang,2013]. Now the production technology of computerized combination balance is becoming mature, its performance and quality have been improved greatly, and has been identified and popularized widely. In order to improve the precision of the computerized combination balance, Peng and Ren proposed an electric control plan of combination weighing control system based on MSC1210[Peng, 2007]. Zhang and Wu proposed a kind of high-precision weighing sensor with multi-scales, and a new intelligent combination weighing system with high resolution A/D converter [Zhang,2015]. Liu expounded the basic structure and principle of computerized combination balance, and designed simulated program for combination calculation based on Lab VIEW [Liu,2011]. Guo and Sun designed a new multi-scales control system, and elaborated the hardware structure and software algorithms of the system based on MC9S12XS128 and MEGA 16[Guo *et al*.,2012].

Application of computer image recognition technology in agriculture began in the 1970s, scholars have made many researches and efforts to the defect detecting, color detecting, size detecting and so on. Ingrdin developed an image processing algorithm based on Fourier expansion to characterize the shape of apples, and the correlation was 0.98 [Ingrid *et al*.,1999]. Mendoza studied the application of sRGB, HSV and L*a*b color model in detection of fruit quality [Mendoza *et al*.,2006]. Huang determined the apple's approximate longitudinal diameter and transverse diameter by utilizing geometrical method, and analyzed the correlation between the measured value and the actual value, and the concordance rate is more than 90% [Huang *et al*.,2006]. Feng took the fractal dimension of color distribution on fruit surface as the grading characteristic, and the accuracy was more than 95% [Feng *et al*.,2002].

Although most researches paid attention either to computerized combination weighing technology or fruit automatic grading technology, there is no research on unifying the two. This paper intends to combine the fruit automatic grading technology and computerized combination weighing technology, and design a kind of computerized combination balance with automatic grading technology.

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PROCESS OF COMPUTERIZED GRADING COMBINATION BALANCE

Traditional computerized combination balance is primarily composed of charging equipment, entry table, main vibrating plate, linear polarization machine, feed hopper, weighing bucket and discharge hopper [Liu, 1999]. In the most cases, after the fruits are graded manually, they are transported to packaging centre, and packaged by computerized combination balance. There is an inefficient fruit grading system in traditional manual grading, which leads to heavier working intensity, unstable grading accuracy, and big grading error. So the balance designed in this paper is added to the automatic grading technology based on computer image recognition, which is based on the traditional computerized combination balance. It combines grading and packaging as a whole process, so it can improve the efficiency and accuracy, and save labors.

Computerized grading combination balance mainly includes fruit lifting equipment, image sampling room, grading equipment, weighing bucket and packaging equipment. A fruit is lifted into the image sampling room, and the image is collected there. The image is used to analyze the size, color, and surface defect of the fruit, and the fruit is graded according to the comparison of the analysis results and the grading standard. Then different grades of fruits go into appropriate weighing area to be weighed, and the weights will be assembled to obtain the optimum combination of fruits to meet the weight requirement. The chosen fruits will be released from the weighing hoppers into packaging area to be packaged. The process of computerized grading combination balance is shown in Figure 1.

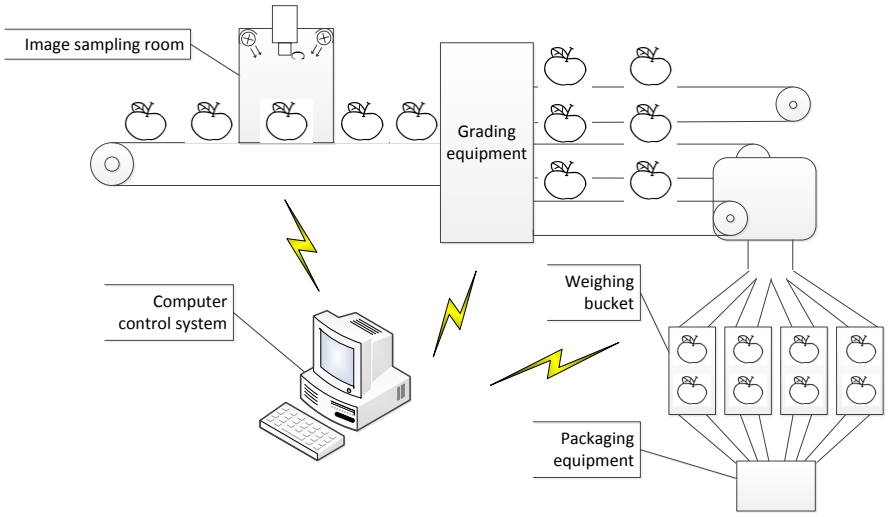

Figure 1. The process of computerized grading combination balance

THE AUTOMATIC GRADING TECHNOLOGY BASED ON COMPUTER IMAGE RECOGNITION

Image recognition is a kind of technology that acquires, analyzes, processes and understands images. Computer acquires the image information, and generates a data matrix, then preprocesses, segments the image, extracts characteristics, and matches with the grading standard. Ungraded fruits are put on a conveyor belt, sent into image sampling room. When the fruit passes the CCD camera, it will be photographed, and the image information of the fruit will be sent to the computer. First, computer preprocesses the image, removes the background and random noise and other irrelevant information to obtain the complete clear image. Then, the size, color, surface defect detection will be done, and the fruit will be graded according to the comparison of the analysis results and the grading standard. The same level fruits are sent into the combination packaging balance to be packaged. The device of fruit grading is shown in Figure 2.

The methods involved in the process of fruit grading are as follows:

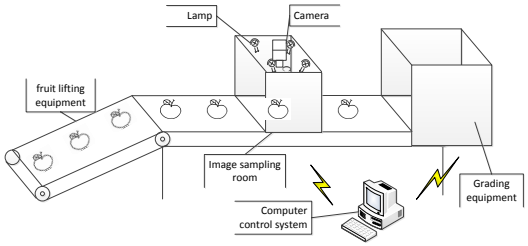

Figure 2. The fruit grading device based on computer image recognition

(1) Preprocess of image. The methods include gray-scale transformation, removing noise and image enhancement. Gray-scale transformation means to convert the color image into black and white image, which can be used to extract the boundary of the image and reduce the interference of color. The averaging method which can obtain the image with soft brightness is adopted to transform the image in this paper. In the process of

image acquisition and transmission, error can be caused by various factors. Removing noise means highlighting the main part of the image, making variation gradient of the brightness smoothly. Most of errors are caused randomly, so the median filtering method is used to remove noise in this paper. Median filtering method is a typical ordering filter, in which pixel value is replaced by gray mid-value of this pixel and its adjacent pixel. Image enhancement means stressing the useful information, weaken the no useful information, and generate new image that is more easily processed and analyzed by computer and human.

(2) Size detection. The technology of fruit size detection is relatively mature, equivalent diameter method is used to obtain the approximate diameter according to the perimeter of the image in this paper. First, the outline of the image is extracted, and the perimeter of the outline is calculated. Based on the relation between a circle's circumference and diameter: $L=\pi d$, the diameter of the fruit is calculated, then it will be compared with grading standard of GB10651-89. For example, the grading standard of apple's diameter is shown in table 1.

(3) Color detection. RGB model and HSI model are common color models. HSI model is used to describe the color features of the image, and H stands for hue, S for saturation of color, and I for intensity. In HSI model, hue histogram is generated, and the chromatic values of apple are replaced by average value of color. The color calculated will be compared with the grading standard, and the color grading standard of apple's coloration is shown in table 2.

Table1 Grading standard of apple's diameter

Grade	Special grade	First grade	Second grade	Off grade
Large size	diameter≥80mm	diameter≥75mm	diameter≥70mm	Diameter<70mm
Medium size	diameter≥65mm	diameter≥60mm	diameter≥55mm	Diameter<55mm
Midget size	diameter≥60mm	diameter≥55mm	diameter≥50mm	Diameter<50mm

Table 2 Grading standard of apple's coloration

Grade	Standard
Special grade	The coloration area of red variety need to be 100%. The color of the whole surface should be uniform and consistent.
First grade	The coloration area of red variety need to be 90%.
Second grade	The coloration area of red variety need to be 70%.
Third grade	The coloration area of red variety need to be 60%.

Table 3 Grading standard of apple's surface defect

Grade	Special grade	First grade	Second grade
Standard	The area of slight bruising injury can't be more than 0.5cm2.	No more than two among bruising injury (<1.0cm2), grinding injury (<1.0cm2), hail injury (<0.5cm2), burning injury (<1.5cm2) are allowed.	No more than three among bruising injury(<1.0cm2), grinding injury (<1.0cm2), hail injury (<0.5cm2), burning injury (<1.5cm2), insect injury (<0.03cm2) are allowed.

(4) Defect detection. SVM algorithm which is relatively mature is applied to detect the defects on apple surface in this paper. First, partition the object according to the threshold value, extract the shape and texture feature values from the object. Then, input these values into the SVM algorithm for pattern recognition to classify the defects. The size, kind and amount of the defect will be compared with the grading standard. The grading standard of defect is shown in table 3.

WORK FLOW AND DESIGN OF THE COMPUTERIZED COMBINATION BALANCE

The work flow of the computerized combination balance is to put the fruits into the weighing hopper, and then package the fruits after combining them based on their weights. For this work process, the constraints to be considered are how to combine the fruits into packages as many as possible so that the weight of each packages satisfy the given requirements. In order to maximizing the profit, the objective function is to minimizing the weight of each package. So we can formulate the general computer combination problem into a linear programming model.

Variable Definition

I: the set of the head number (weighing bucket) of the computer combination scale.

J: the set of fruits for each weighing hopper.

a_{ij}: the weight of the fruit j in the bucket i.

y_{ij} is a 0-1 variable. $y_{ij}=1$ when the fruit j in the bucket i of the computer combination scale drops for packaging, otherwise $y_{ij}=0$.

α : allowed deviation under the target weight,

β : allowed deviation above the target weight.

M : the weight of each individual package.

Mathematical Model

For general situation, we establish mathematical model as follows:

$$min\, z = \sum_{i \in I} \sum_{j \in J} a_{ij} y_{ij} \quad (1)$$

$$M - \alpha \le \sum_{i \in I} \sum_{j \in J} a_{ij} y_{ij} \le M + \beta \quad (2)$$

$$y_{ij} = 0,1 \quad i \in I, j \in J \quad (3)$$

Function (1) is the objective function to minimize the weight of each package. Constraints (2) ensure the weight scope of each independent packing, and represent that the weight of each package is as small as possible within the limitation. Constraints (3) are the illustrations of variables.

Algorithm

To solving the model, we design the following algorithm.

Step1. Label the scale that for double fruits with 1,2,3,4 and for single fruit with 5,6,7.

Step2. Calculate weight of each scale after dropping fruits on the scale based on the loading capacity.

Step3. Calculate the sum of fruit weight S in double scales. If S doesn't exceed the limit of deviation, go to step 5. Otherwise, go to step 4.

Step4. Combine each fruit in the scale for single apple with combination in step 3, and find one single fruit with which we can obtain the most accurate combination result.

Step5. Package the selected fruits.

The algorithm is compiled by MATLAB 7.1.

SIMULATION

String bag packing of apples is taken as an example in this paper. An ungraded apple enters the computerized grading combination balance, the image is collected in the image sampling room, and processed by computer to obtain the size, color and surface defect which will be compared with the grading standard of apple in GB10651-89. The graded apple enters the corresponding weighing area to be weighed, and is packaged with other apples to meet the weighing requirement according to its weight.

For the string bag packing of apples sold in supermarket, the weight of every individual package is 2000g. Assume that each apple weighs 200g to 250g, so there are 8 to 10 apples in every individual package. A kind of multi-scales combination balance for string bag packing of apples is designed in this paper. There are four weighing hoppers (set as B) each of which weighs two apples, and three weighing hoppers (set as C) each of which weighs one apple at the same time. If the total weight in A reaches 2000g, package them; otherwise, choose one or more apples from C such that the total weight of the chosen apples from C and all apples from B satisfy the weight requirement, then package them. The design of the computer combination balance is shown in Figure 3.

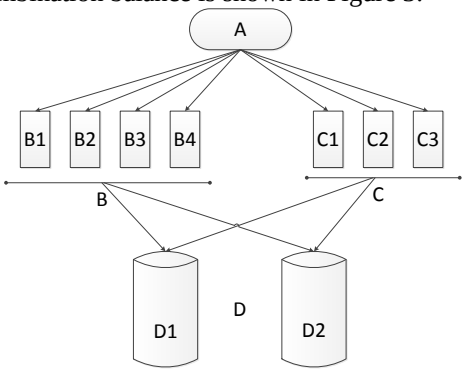

Figure 3. Design of the computerized combination balance

Parameters

According to the mathematical model, the parameters in this problem include the weight of each apple a_{ij}, the total weight of each string bag M, lower deviation α, and upper deviation β. a_{ij} is created randomly, and is normal distributed, the mean is 225g, and standard deviation is 8.5g. M=2000g, α=0g, β=50g.

Analysis of the Results

Using the MATLAB program of the algorithm, we generate ten group data of apples' weights listed in table 4. The weight in each weighing hopper in B is the sum of two apples' weights, and the weight in each weighing hopper in C is one apple's weight. The calculated results are shown in the last two columns of table 4.

In table 4, the total weight of apples in group 4 is lower than 2000g, but it will exceed the upper deviation if any other apples in C added in this group. Since the total weight of apples in group 4 is very close to 2000g, so they are packaged. From the results of the example, we can see that the algorithm and program can be applied to design a computerized combination balance effectively, and the total weight of each package obtained by our algorithm is very close to the parameter M.

CONCLUSION

In the process of traditional fruit commercialization, after fruit growers picking fruits, they are graded according to the size, color, surface defect artificially, then assemblers purchase fruits according to their grades, and transport to the package center. After packaged, those fruits enter the market. The design of computerized grading combination balance combines the two links as one, and the

assemblers can purchase all grades fruits and transport to the package center to grade and package them. The application of this machine can rebuilt the workflow, avoid the fruit degradation caused by the damage in transit, save labors greatly, and avoid the error caused by subjective factors. At the same time, development, application and improvement of electronic weighing equipment are of great importance in improving the automation in the field of packaging and food machinery.

In this paper, a new computerized grading combination balance is designed on the basis of analyzing the fruit grading technology and the workflow of traditional computerized combination balance, and the string bag packing of apples is taken as an example to demonstrate the feasibility of this kind of balance theoretically. And the parameters can be adjusted to package different specifications of apples.

Table 4 The results of the simulation (unit: g)

Weighing hopper / Groups	B1	B2	B3	B4	C1	C1	C3	The chosen hopper in C	Total weight
1	441	460	455	435	223	221	212	C3	2003
2	435	454	437	454	223	221	224	C2	2001
3	463	440	450	443	223	209	224	C2	2005
4	461	429	443	442	223	201	224	C3	1999
5	446	450	454	435	223	201	223	C1	2008
6	450	444	461	450	223	201	223	C2	2006
7	441	466	454	461	223	225	223	C3	2045
8	430	467	445	447	223	225	227	C1	2012
9	456	431	447	459	227	225	227	C2	2018
10	442	441	460	459	227	231	227	C1	2029

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