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Review
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SYSTEMS FOR OPTIC COLOR CALIBRATION
SISTEMI ZA OPTIČKO KOLOR SORTIRANJE

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ABSTRACT

Color sorting machines are used for optical sorting of fruits, vegetables, seeds and other products. The color sorter creates a picture of products flowing through the machine and compares these images with predefined. If a product does not satisfy the requested criteria, it will be rejected from the machine. User Interface (UI) is used for monitoring the machine's operation by the customer and direct control over its functions. The color sorter creates a product image using cameras, lasers or integrated-combined system of these two devices. The pneumatic nozzles reject bad products from machine. This paper shows the new system integrated optic color sorter which consist of the subsystem for product recording and the pneumatic unit for rejecting bad products.

***Key words**: optical sorting, fruits and vegetables, camera, laser.*

REZIME

Mašine za optičko sortiranje koriste se za sortiranje voća, povrća, semena i drugih proizvoda. Kolor sorteri stvaraju sliku objekta koji se kreće kroz mašinu i upoređuje sa zadatom slikom. Ukoliko proizvod ne zadovoljava zadate kriterijume, biće odbačen sa mašine. Korisnički interfejs koristi se za praćenje rada mašine i kontrolu funkcija. Kolor sorter kreira sliku proizvoda upotrebom kamere, lasera ili integrisanom kombinacijom oba uređaja. Pneumatski izbacivač odbacuje loš proizvod sa mašine. U ovom radu prikazani su novi integrisani sistemi optičkih kolor sortera koji se sastoje od podsistema za snimanje i pneumatske jedinice za odbacivanje loših proizvoda.

***Ključne reči:** optičko sortiranje, voće i povrće, kamera, laser.*

INTRODUCTION

Nowadays, food quality is the main criteria for selection of technologies and equipment for its processing. Before any final processing and packaging of agricultural products, especially fruits and vegetables, as well as seeds, it is necessary to separate biologically unsatisfactory products. Until the present time, this procedure was performed manually and required a lot of time and human labour. With enlarged request for the consumption of high quality fruits and vegetables, there was a need for new technologies and greater processing capacities. The solutions are sought in the mechanical way of sorting fruits and vegetables.

MATERIAL AND METHOD

The operating principle of color sorting machine consists of the following: the product (fruits, vegetables…) is passing through the machine and cameras and/or lasers are recording it. The obtained images are compared with the predefined criteria of good and bad product. These criteria are related to color, physical and mechanical properties of the product. If the product meets the given criteria, the machine will treat it as a good product. If not, the machine will treat it as a bad product and it will be removed from the machine. The disposal is done in the subsystem for bad product removal that consists of a large number of pneumatic ejectors, Figure 1.

The sorting system consists of the following subsystems integrated into one unit (*Blasco et al*, *2009*; *Forbes, 2000; Lihong et al, 2006*):

- Subsystem for transport of the product;
- Subsystem for product recording (cameras, lasers);
- Central control system;
- Subsystem for bad product removal.

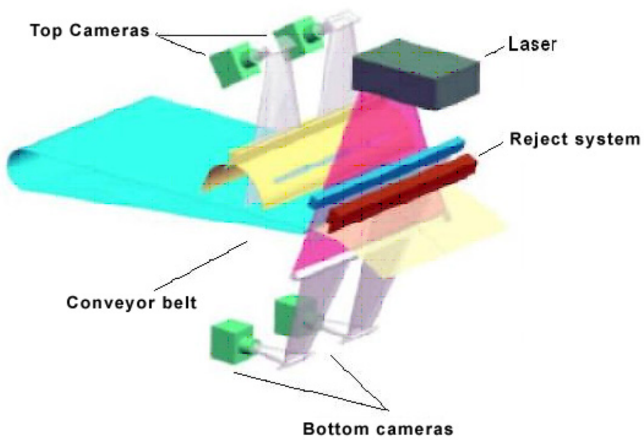

Fig. 1. Laser and cameras integrated system (Gonzalez and Woods, 2002)

The subsystem for transport of the product through the machine can be carried out as:

1. „In Air" system - for free fall transport of the product;
2. „Belt" system - for product transport by means of belt conveyor;
3. „Channel" system - for channel transport of the product.

Color sorters are fed with the product using equipment that is directly before them in technological lines. These are usually different vibratory calibrators or conveyors that provide even distribution of the product. From vibratory conveyor the product is introduced to the subsystem for transport of the product. This is usually conducted by means of belt conveyors. The belt has exact profile and color, depending on product that has to be transported. On the input side of the machine there is a rotating drum called „ the product stabilizer" which ensures that the relative speed of the product is equal to zero, in relation to the belt of the conveyor, and also prevents axial movement of the product on the belt. The speed of the belt changes depending on the product characteristics (*Marković et al, 2009*).

The subsystem for product recording consists of one or more cameras, one or more lasers or integrated system with cameras and lasers. This subsystem is recording the product on the belt. The obtained images are compared with the predefined criteria. The main criteria are color, physical and mechanical characteristics of the product. The color criteria apply to the following: the color of the transported product is compared with the predefined colors, and there are three basic categories of the type of the color: the color of the good product, the color of the bad product, and the color of the background. If the color of transported product matches the color of good product, that product will be recognized as satisfactory and will be transported to further processing and packaging. The product whose color matches the color of bad product will be discharged from the machine (*Ohnon and Hardia, 1997, Đević et al., 2005)*.

The criteria of product recognition based on physical and mechanical characteristics entail the following: if the transported product does not have the physical and mechanical characteristics of the predefined good product, it will be removed from the machine. In other words, when the product, which is transported through the machine, is recorded by the optical device and if its characteristics do not match the characteristics of the good product, it will be detected as a bad product and discharged from the machine. If recorded characteristics match the characteristics of the good product, it will continue to further processing and packaging.

Cameras are optical devices which recognize the color and lasers recognize physical and mechanical characteristics of the material.

Cameras which are used can be:

Black and white (BW)

Color

The BW Camera recognizes only black and white color, and combination of these two colors. The color camera compared to the BW camera, recognizes the whole range of colors which are originated from combination of three basic colors: red, green and blue. Each basic color has 255 shades, so the complete range of colors from combination of these three is 16.58 millions *(Onwubolu, 2005)*.

Each color which originates from combination of three basic colors, has its own location in the so-called “color cube”. “Color cube” is a color model consisting of combinations of red (R), green (G) and blue (B) color.

At the beginning of the coordinate system there is the absolute black color, which has coordinates (R, G, B) 0, 0, 0. The absolute white color has 255, 255, 255 coordinates. All other colors have coordinates within these two extreme values, figure 2.

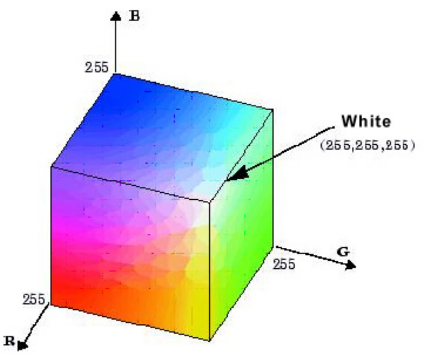

Fig. 2. The color cube (Gonzalez and Woods, 2002)

In order to achieve a high quality picture, the color sorting systems are using CCD cameras. Part of the light goes through camera lenses, falls on sensor surface and generates the analog electrical signal. The analog signal is converted into digital by the A-D converter and then sent to the main processing unit which creates the final product – digital photo, figure 3.

Since all camera sensors are black and white and are not able to detect colors, just the intensity of light is detected, when the Bayer mask is added.

Besides the previously described systems, the three-CCD system is also used. This system contains three separate CCD devices. Each of these device detects red, green or blue light. The light deflected from the lens is separated through the trichromatic prism, which deflects appropriate wave lengths to designated CCD device. Compared to the system with one CCD device, the system with three CCD devices generally generates higher quality images *(Oppenheim and Schafer, 1989)*.

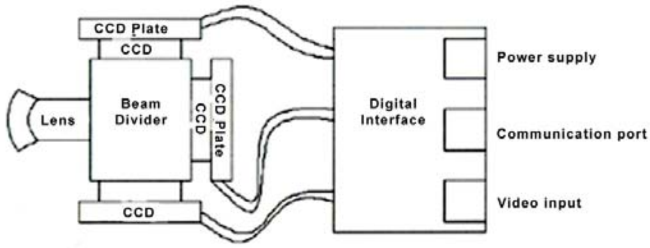

Fig. 3. The camera block diagram (Gonzalez and Woods, 2002)

Figure 4. shows the image of an apple which passed color sorting. Image 4a shows the realistic image of the same apple. Figure 4b shows a segmented image of the same apple which shows good skin (surface), stem and damaged parts of the apple. Stem and damaged parts are recognized as a bad product, so pneumatic ejectors are activated and the product is rejected as bad.

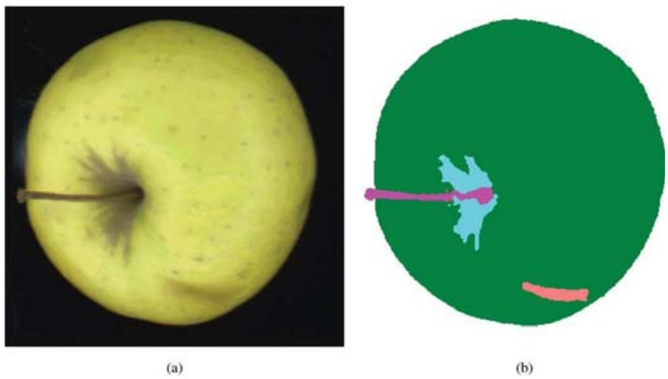

Fig. 4. (a) Original image captured by the camera (b) segmented image showing the skin, the russeting, the stem and the damage regions (Key Technology)

Laser is a device which transmits coherent photon beam. The laser light is monochromatic (light with the same wave length) and directed in narrow beam. The beam is coherent, which means that electromagnetic waves have the same frequency and they expand in one direction.

The product is transported on conveyor belt and recorded by the laser. The recorded image is compared with the predefined criteria based on physical and mechanical characters. The laser is using polarized light to compare the recorded image with the predefined good/bad product. The information returned from the product is “read” by polarized light of the predefined product

(Week, 1996). The light beam is generated by conversion of unpolarized light to polarized. When the unpolarized light is run through the polarization filter, half of the light intensity oscillate in one planar and appears as polarized light, figure 5.

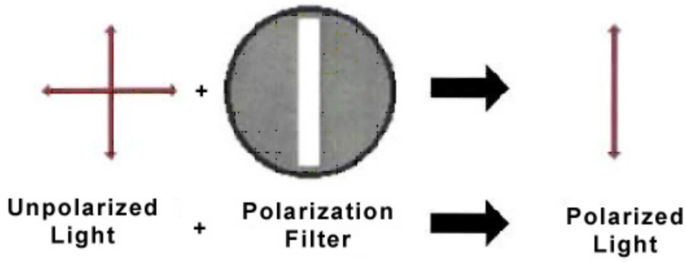

Fig. 5. The scheme of transformation from non-polarized to polarized beam light, using the polarization filter (Gonzalez and Woods, 2002)

Laser IC system working principle goes as follows: the laser transmits the light beam which is transferred to polygon by rotating mirrors. The rotating polygon is the assembly of mirrors in octagonal shape, which rotates at very high speed. The rotating polygon transmits the laser beam to conveyor belt which transports the product.

The laser records images of the product on the conveyor belt and compares images with the predefined signals of good/bad products *(Srećković et al, 2009*). If return signal of the recorded product does not fit to predefined image of the good product, the recorded product is considered to be bad. The information about the bad product is transmitted to central processing unit which activates the reject system, figure 6.

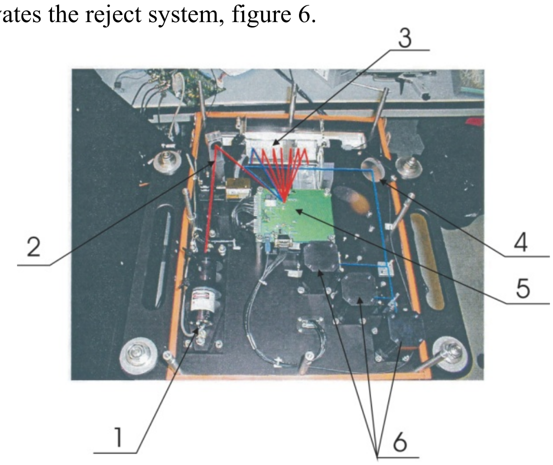

Fig. 6. Integrated laser system components:
1- laser, 2-mirror, 3- mirror which transmits the laser beam to the rotary background, 4- mirror, 5- rotary background, 6- receiving device for reception of deflected laser beam (Gonzalez and Woods, 2002)

The central processing unit, figure 7, is used for color sorting management. Optical devices (lasers and cameras) are connected with the IP computer, which receives signals from optical devices in form of digital information in pixels, processes them and sends to the sorting computer in a form of coded object information. The A/D converter is converting analog signals into digital. The sorting computer receives the information from the IP computer, calculates them, and determines which nozzle should fire and at what time. Machine operation and control is performed in real time through touch screen displays, or remote computer.

The subsystem for discharge of bad products is an executive operating body of this system. It consists of large number of pneumatic ejectors which are activated after receiving the information from the computer about bad product. After receiving the information, adequate nozzle above exactly defined product is opened and the product is discharged from the system by means of high pressure air. Pneumatic ejectors are usually placed in one row above the conveyor belt within the system because of the complete coverage of the product area. The number of nozzles depends on belt width, the wider it is, there are more nozzles and vice versa. Communication between computers is done via "fire wire" connectors. They transmit data with high speed to/from digital devices. The Ethernet connection is used for the transmission of information necessary for configuration and communication between the devices. All system levels of communication are linked by the high speed Ethernet connection *(Russ, 1995)*.

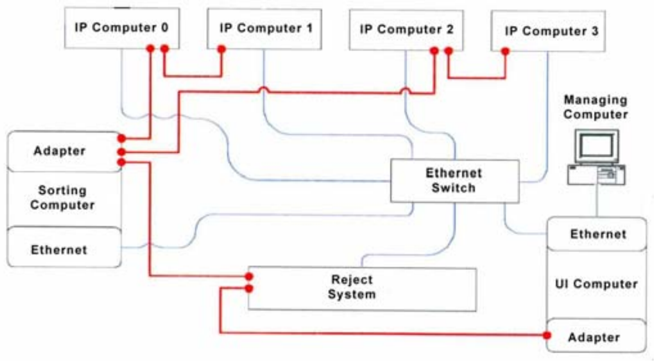

Fig. 7. CPU scheme (Gonzalez and Woods, 2002)

DISCUSSION

The testing of the integrated system with cameras and lasers for optical color sorting has been done in the factory for food processing „ITN Eko Povlen", Kosjeric in November and December 2009 with frozen berries, especially frozen raspberries as the most delicate fruit. Table 1. presents data obtained by parallel manual and mechanical sorting of raspberry with an equal number of workers on the lines. The processing capacities per working hours and raw material consumption per worker are shown. Based on these tests, the conclusion is that at the same conditions, the processing capacity of the machine for color sorting is five times higher compared to manual sorting with the same number of workers. The quality of obtained product is absolutely higher, the permanent quality is ensured, as well as 24 hours continuous operation with capacities up to 6 t/hr for raspberry, or up to 15 t/hr for frozen vegetables and other product.

Table 1. Comparing data of raspberries sorting (Blasco et al, 2003)

Raspberry sorting	Capacity (kg/h)	Percentage (%)	Consumption of raspberries per one worker (kg/worker)	Percentage (%)
Machine	1974.33	100	179.48	100
Manual	386.25	19.56	35.11	19.56

Table 2. is showing the percentage of bad raspberry discharged from the system. By bad product we mean raspberry with stem, mould and dried raspberry. These fruits are considered unsatisfactory and have to be removed from further processing and packaging. The values that are shown refer to the amount of the bad product at the inlet in the system and the amount of the bad product rejected from the system. The percentage of rejected product compared to the input quantity is also shown, which verifies all the parameters given in this paper.

Table 2. The mass and the percentage of rejects from the machine (Blasco et al, 2003)

The product	Raspberries with stems		Raspberries with dry spots and mold raspberries	
	gr	%	gr	%
Inlet in the system	2000	100	8900	100
Rejected from the system	1760	88	6100	69

CONCLUSION

Fruit and vegetable processing is moving in the direction of full automatization with minimal human involvement. Optical sorting systems represent major progress in fruit and vegetable processing technology. A wide range of applications and relatively easy transition from processing one type of fruit/vegetable to another makes them very significant. Further development of these systems will significantly contribute to the increasing product quality, reducing costs, especially labor costs and increasing production capacity, which the results of the initial studies presented in this paper have confirmed. The application of the integrated systems with cameras and lasers, along with the development of new facilities for the preparation and quick freezing of fruits and vegetables will significantly contribute to the future development of new technologies in the frozen food industry.

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