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색에 따른 사과 분류기

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Apple Sorting Machine by its Color

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요 약 본 논문에서는 인간의 노력을 줄이고 정확성을 높이기 위해 사과의 색을 기반으로 하는 분류 시스템을 제안하였다. 제안된 분류 시스템은 카메라, 모터 및 라즈베리 파이로 구성되어 있고, 미성숙, 성숙, 익은 등으로 총 4가지 종류의 사과를 분류할 수 있다. 시장에서 다양한 종류의 사과를 100개 구입하여 무작위로 선택하여 평가하였다. 정확도는 95%였고 처리 시간은 사과당 약 8초였다. 제안한 시스템은 인력 감축에 유용할 것으로 예상된다.

• 주제어 : 색채 분석, 라즈베리 파이, 카메라, 과일, 분류

Abstract This paper presented the basics of using a sorting system to reduce human effort and increase accuracy. The proposed system has consisted of a camera, motors, and a Raspberry Pi. This system can classify the apples as immature, mature, ripe condtion, and etc. In this experiment, 100 apples were randomly selected by purchasing various apples from a local market. The accuracy percentage was 95% and processing time was about 8 seconds per each apple. The proposed system could be useful to reduce labor.

• Key Words : Color analysis, Raspberry Pi, Camera, Fruits, Classification

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Ⅰ. Introduction

Producers often rely on agricultural products and need to obtain high-quality agricultural products. Moreover, fruits are taking up an important place in human consumption. At present, the number of fresh fruits consumed has increased. Automated sorting of agricultural products is particularly beneficial because of the increasing demand for different quality food with different affordable prices by several groups of customers of different living standards. According to the study, fruits are sorted by maturity before the market. In the ripeness assessment, sorting according to the color has more meaning than sorting according to the shape or dimensions specification. One of these systems is the sorting of products according to the surface color or its light reflectance. In this study, a sorting machine developed according to the designed apple color depending on its color wavelengths or reflectance. The sorting of the fruit is an essentially mechanical process in which difficult work is needed. Machines can perform mainly tedious duties that are superior to humans. For instance, an employee who has sorted the fruit for a long time eventually forgets to recognize the color of the product. However, the machine does not have these limitations. So, the automatic classification system not only speeds up the processing time but also reduces errors [1].

This paper utilizes the Pi camera and microcontroller using the open-source Linux method to recognize apple fruit's capture. First of all, the fruits that are going to be classified are put into container, then the apple's container slides through a path that has installed the Pi camera. It describes the fruit color detection, and then the actuator is driven by the servo motor that separates the fruits based on the color. Laboratory automation systems can distinguish the fruits of the exterior and interior. However, machine vision is more effective for measuring outer parameters [2]. The maturity of the lime fruits was measured using a camera mounted on the top of the object. Using cameras in the above method can generate much energy and increase heat. Despite of the drawbacks, the maturation of lime fruits with scratches and black spots could not be detected by the camera's signals. The accuracy was up to 93.3% [3]. The model of the robotic jaw is connected with the Raspberry Pi and a USB camera. It senses the object with the help of an ultrasonic sensor. It detects the color, and accordingly moves near to do its sorting, identifying the color, picks up, and takes it to the specified position. This proposed system gives better results than the identification of colored objects by the robotic arm that can be controlled automatically for industrial purposes [4].

We proposed a machine vision system for automatic apple sorting based on previous knowledge documents. As a hardware camera system, the sorting machine is fast with an easily programmable sorting system. Initially, the software and hardware needed to build the OpenCV-python system were chosen using computer vision. The camera is utilized to categorize the good and defective fruits during the experimental work, such as the cameras needed calibration.

Ⅱ. Methodology

2.1 System configuration

This study presents the design, development, and performance evaluation of a prototype system that automates color sorting using the domestic market hardware.

There are three main components to designing an embedded system with a machine interface for quality control. The first is to design the system and its parts from a mechanical point of view. The second is to integrate the Raspberry Pi microcontroller with other electronic devices. The third is to make a program code to performs at the microcontroller.

2.2 Mechanical design and assembly

Mechanical design includes the types of bearing, conveyor roller selection, conveyor belt selection, and load distribution measure on the system structure. Figure 1 shows the mechanical design and components and creates a 3D model by using SolidWorks 2013 software.

1. Components of parts selection (roller shaft, conveyor belt, bearing, and frame)
2. Material selection
3. System support structure
4. Conveyor belt assembly
5. Final assembly

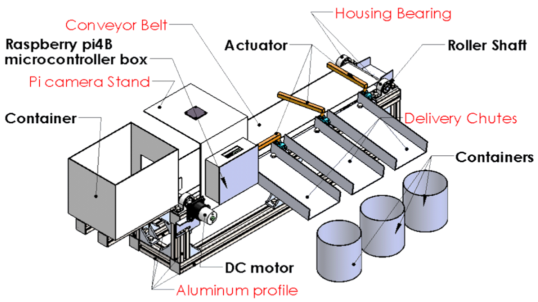

Fig. 1. Mechanical design and components

2.3 Control system

After installing the mechanical parts and then the electrical components are attached such as the Raspberry Pi controller, Pi camera, motor control, and a socket to the respective part of the frame. The control system in Figure 2 shows the electrical circuit diagram of the sorting machine, the development of the software, and the inclusion of all components required to join the project's purpose.

The software starts working by capturing images from the camera. Processes were specified in the software algorithm. The algorithm first inspects the apple's color by using captured information. After the achievement of the transaction, the color information of apples is shown on the monitor. In the studies, inspection and evaluation of the images taken from the camera has been performed. The OpenCV is an easy-to-use and simple open-source computer vision library for python, and image software was used to make sense of images for computers.

In the algorithm, the apple image is obtained by comparing the taken image with a predefined image. Apple's color was determined by processing this image. These values were compared to predefined color values and the color class of the apple was determined.

The electrical unit consists of a Raspberry Pi 4 model B microcontroller, a Pi camera, a servo motor, and a DC motor. Initially, a 12V DC motor has provided to operate the roller shaft. The proposed model has a conveyor belt driven with a 12V DC motor on which the fruit moves in a definite direction. The Raspberry Pi microcontroller uses a servo motor and conveyor belt based on the fruit position, and the Pi camera has captured a fruit and verify the good and bad fruit based on color. The Pi camera is located at the top of the conveyor belt. The Pi camera detects the fruit as the fruit passes through the conveyor belt. When the Pi camera is capturing fruit images the program converts the RGB value to the first captured image's HSV value considers it as a reference, then compares the reference value to the next image.

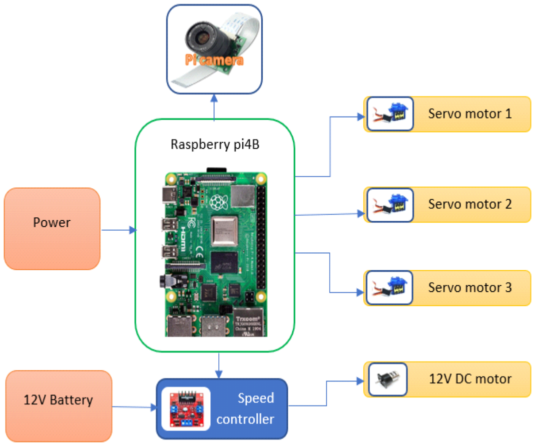

Fig. 2. Electrical circuit diagram of the sorting machine

2.4 Fruit detection

Firstly, after the container placement, the machine collects and moves the fruit on the conveyor belt. The DC motor is directly to drive the conveyor roller shaft. DC motor rotation rate controls the speed controller and then fixed the conveyor belt together with a roller shaft, carrying the fruit and transporting the designated fruits to the designated place.

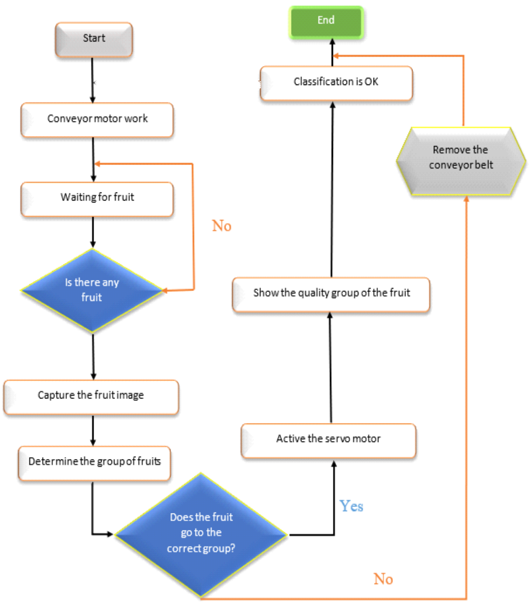

Fig. 3. The sorting algorithm

The camera arrangement is at the top of the conveyor belt. Because the apple to be captured image has been homogenous, to detect the fruit in front of the camera. Power the Raspberry Pi and then operate the python that we have created. The detection camera was able to detect red, yellow or green objects and change direction by a servo motor to sort the object in the proper place and then slid the fruit into each container. Then the camera detects fruits in defects; all of the servo motors do not operate so that defective fruits fall directly at the end of the conveyor belt line.

III. Experimental research

3.1 Experimental procedure

Apple Fuji in Korea was analyzed for this research. One hundred apples in different sizes were randomly picked from the Anseong-si local market. Apples were selected by careful visual inspection, transferred to the laboratory until the experimental procedure. In this study, the 100 randomly selected apples.

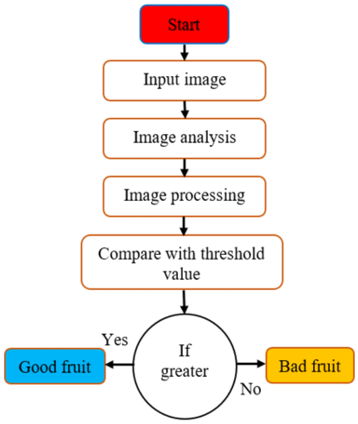

Fig. 4. Flowchart of the soritng system

The following steps were used to analyze a feature extraction.

1. Capture input images using a pi camera and collect some images as database images. It includes the good as well as the bad quality images.
2. The RGB image is converted to HSV color. Then the lower and upper ranges are defined. Then set the image of the binary image. Lastly, convert a single-channel mask back to 3 channels.
3. In extracting a colored object to detect the red, we use the HSV color threshold script to determine the lower/upper thresholds. The HSV color space also provides information about the image that it either presents or not in this system.
4. Using the input image, we obtain the mask images. The cover image is available in black and white.

The apple sorting machine is easy to start controlling the operation of the system. This project design has a roller conveyor belt that accurately moves the object with a 12V DC motor's assistance. Initially, the machine was integrated with a 12V power supply and drove the conveyor belt through a speed controller and a 12V DC motor-roller shaft. Housing bearings support roller shafts at both ends.

An aluminum T-slotted profile supports the entire arrangement. Another acrylic plastic sheet stand is used to support the Raspberry Pi microcontroller and Pi camera. The mechanical structure consists of a 30 mm×30 mm aluminum T-slotted profile having a length of 900 mm, width 160 mm, and height 330 mm. Roller shafts with a diameter of 10 mm are used to drive the PVC conveyor belt. The conveyor belt width is 100 mm and length 1300 mm. Pillow block bearings support roller shafts at both ends. 12V DC motor encoder-mounted helical gear type mechanism is used for precision movement without slipping. The roller shafts run the conveyor belt through friction, and the RPM is 507~6 revolutions per minute.

The USB plug from the Raspberry Pi is connected to a 220V power supply through a 220V to 5V adapter and it also supports the Raspberry Pi and servo motors. As the servo motor gets power, the operation is beginning. The PC monitor and keyboard are connected with Raspberry Pi through the HDMI cable and USB plug. Then input the Raspberry Pi code into the terminal in the python program language and press enter. Therefore, the system has automatically arranged the program given into the Raspberry Pi. The reference picture saving address has to be mentioned in the terminal, and the first object has to be placed on a conveyor to be used as a reference color. After receiving the reference color, the sorting machine classifies the products with the reference color. Lastly, different objects have been arranging on the conveyor belt for sorting, and the machine compares the images with the reference color and removes the defect from the conveyor belt. As the sorting machine gets faulty fruit, then the conveyor has been carried to the end of the conveyor belt.

Preliminarily, the maximum and minimum of R, G, B values Cmax and Cmin should be determined and their difference M is considered in the following equations [5]. Calculating the values for each pixel, we get an image in the HSV color space.

The hue (H) is calculated,

$$H = \begin{cases} 0, & C_{max} = 0; \\ 60 \times \dfrac{G-B}{M}, & C_{max} = R; \\ 60 \times \dfrac{B-R}{M} + 120, & C_{max} = G; \\ 60 \times \dfrac{R-G}{M} + 240, & C_{max} = B; \end{cases}$$

The saturation (S) is calculated,

$$S = \begin{cases} \dfrac{M}{C_{max}}, & C_{max} \neq 0; \\ 0, & C_{max} = R; \end{cases}$$

The value (V) is calculated,

$$V = C_{min}$$

Color	RGB Values	HSV Values
Green	0, 255, 0	60, 255, 255
Yellow	0, 255, 255	30, 255, 255
Red	0, 0, 255	0, 255, 255

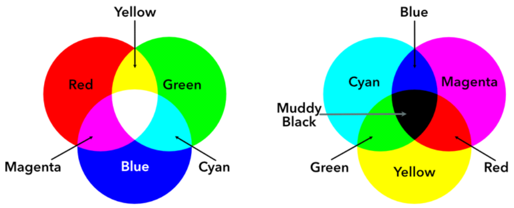

Fig. 5. RGB value to HSV value colors model

Ⅳ. Results and discussion

We use three different fruits of circular object samples red, green, yellow, and defective fruits for testing. DC motor drives roller conveyor shafts at design speed. In capturing the images with a

5-megapixel Pi camera, the fruit must reach underneath the Pi camera as shown in Figure 6.

Fig. 6. Capture fruit with the Pi camera

The Raspberry Pi microcontroller successfully analyzes the object image according to the specific threshold value for the corresponding color. The machine successfully separates the defect and then removes it from the conveyor belt. Also, the sorting machine has sorted the good fruits with a micro servo-operated actuator. Figure 7 shows that a Pi camera takes the fruit image.

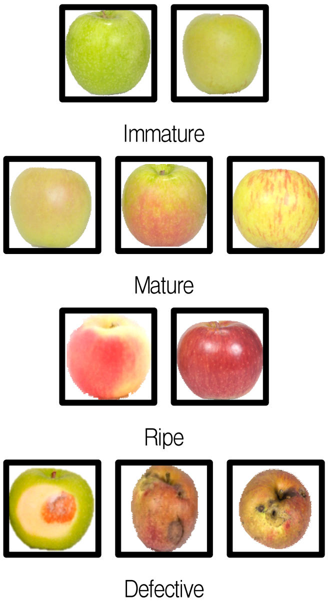

Fig. 7. The fruit classification examples according to the colors

The Pi camera takes the input image. Image is captured in the experimental lab. Pre-processing on the pictures is done using computer vision OpenCV libraries in python by importing library algorithms to determine immature, mature, ripe, and defective fruit and accurate results are obtained immediately within 2 seconds. According to the proposed algorithm, after detecting the image in which apple fruits are converted an RGB color model to an HSV color model. Figure 8 shows the image analysis.

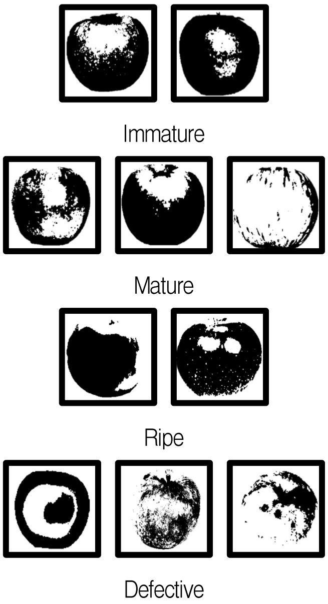

Fig. 8. Classification of image analysis

The proposed algorithm results were applied to test a collection of 100 fruit images, including 90 images for good quality fruits and 10 images for the lousy quality of fruits.

The experiment results were conducted on various images of apples as shown in Table 1.

Table 1. Results of study and analysis of apples in sorting based on maturity

Class	No. fruit	Correctly classified			
		Manual sorting	Manual (%)	Machine vision sorting	Machine vision(%)
Good	90	80	89 %	90	100 %
Bad	10	9	90 %	9	90 %
Total	100	89		99	
Accuracy rate			89.5%		95%

Ⅴ. Conclusion

We proposed the sorting system that reduces manpower, improves accuracy, and increases the speed of production. The design of software, hardware, and mechanical parts of the automatic apple sorting system was explained and discussed above. We studied the apple sorting machine's design according to the color sorting and machine vision features in our experiment. This study also considered the sorting machine equipment to get flexibility with the sorting mechanism and nature of apple fruit. Besides, the DC motor application makes the conveyor belt running smoothly. In this condition, the apple fruits need to be classified, so we used the OpenCV program according to the color classification system sample. So, we have to understand the Pi camera's position to detect the fruit the Pi camera installs not only faraway but also close up from the detected sample fruit.

In agriculture, fruits have to be distinguished by their properties such as size, color, shape, and texture, so researchers need to design and develop different systems for each product. This system is not only a creative section for this paper but also a possible solution for another product, such as other similar fruits. The system can sort out into three colors: red, yellow, and green. In determining the surface colors of each ripeness rate for apples, we calculate its accuracy in color sorting. Finally, the average accuracy rate in sorting is 95%. To be able to use this prototype machine in marketing and industry, it has to be understood that some improvements are needed to increase the capacity

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