Distinction of Green Sweet Pepper by Using Various Color Space Models

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1. Introduction

1.1 Background

Every production system needs to obtain higher quality products at a lower cost in order to be competitive. One solution to this challenge is to develop automatic systems that replace manpower in tasks when a person performs worse than an automatic device in terms of precision, repetitively and working cycle. Probably, harvesting is the process that has received the least amount of technological development for satisfactory automation. In agriculture, some damage resistant agricultural products like olives and almonds can be harvested using trunk or branch shakers. However, harvesting of delicate fruits, such as tomatoes, oranges, apples or strawberries for the fresh market cannot be harvested using aggressive methods such as shakers. If these methods were used, the fruits could be damaged by impacting the branches of the tree during the fall or directly falling down on ground, and therefore fruit would loss the quality and results in reduction of trading cost in the fresh market. The current method for collecting these type of fruits is hand harvesting. This method implies the use of temporal manpower which increases the final cost of the fruits in the market.

1.2 Problem Identification

The solution for the harvesting of delicate fruit without the drawbacks of manual operation may be the use of automatic systems capable of performing an individualized collection, using selective strategies to harvest only fruit with the desired conditions, and at the same time, providing a system able to work 24 hours. To obtain this automatic system there are three main problems to be solved: (1) the guidance of the robot through the crops, (2) the location and characterization of the fruit on the trees, and (3) the grasping and detachment of each piece. The first factor is not crucial and can be solved using one operator to guide the robot in the plot or adopting line tracing moving base system. The other two problems have received remarkable attention during the last thirty years, although no commercial harvesting robot is available. This paper presents solution to discriminate the location of fruit which is part of second problem mentioned above.

1.3 Scope for Research

Sweet pepper is the 4th most important fruit vegetable in Japan grown on approximately 357 hector area of land which needs not only high man power but also high input energy consumption during harvesting operation leading to increase in labor cost and production cost [1]. This issue also relates with the decreasing population of Japan in recent decades [2]. On the other hand, as both, green sweet pepper and leaves has almost same color and due to that it is very difficult to recognize them separately during automatic harvesting. Hence, by considering these issues, a sweet pepper was selected for the study. This paper focuses on location and characterization of sweet pepper during harvesting operation in the greenhouse horticulture.

2. Sweet Pepper Harvesting Robot

2.1 Concept of Harvesting Robot

Fig. 1 shows the overview of the concept of sweet pepper harvesting robot. The harvesting robot is composed of three main units; first unit refers to recognition system in which identification and location of the fruit confirmed, second unit refers to picking system in which grasping of fruit and then cutting operations performed; and third unit refers to moving system in which the programmed base sub-unit of the robot moves in the furrows during harvesting operation in greenhouse. In the recognition system, CCD cameras were used to capture the images. The picking system composed of gripping and cutting parts which help to grasp the fruit first and then detach the fruit from stem. The moving base system includes crawling tracks and wheels controlled by line tracing program and carries the robot manipulator on it.

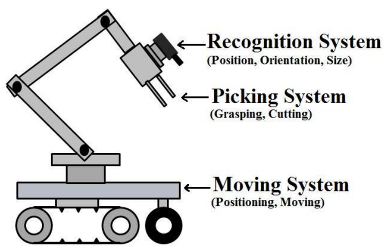

Fig.1 Concept of Sweet Pepper Harvesting Robot

2.2 Inclined Trellis Training System in Greenhouse

In the conventional plant training system, the sweet pepper plant grows in upward direction and leaves cover most of the canopy area which results in difficulties in fruit recognition and manipulator movement towards the fruit. Unlike the human eyes, a robot with visual sensor cannot distinguish one object with a certain color from another object with a similar color and determine the shape of an object; may not be able to detect the fruit which is entirely or partly covered by the leaves. In addition to this, the stems and leaves are more likely to become obstacles when the manipulator tries to approach the fruit [3].

The advanced plant training system helps to solve these problems by separating fruits easily from leaves and stems. The use of strands or threads helps the plants to grow in almost V-shape which makes convenient to harvest sweet peppers without any obstacles and reduces recognition errors. Figure 2 represents inclined trellis training system in greenhouse adopted to grow the sweet pepper plants.

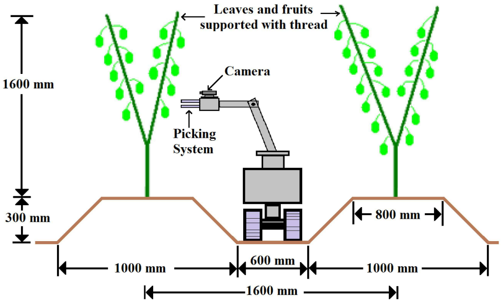

Fig.2 Inclined Trellis Training System

3. Recognition System

3.1 Visual Sensing System

The image processing system composed of two color CCD cameras, image grabbing unit and image processing software. For improving the fruit recognition rate, system was equipped with LED lightening ring around the camera neck [4]. The PicPort of Leutron Vision image frame grabber was used to capture the real time images. For image processing, Halcon software from MVTec was utilized.

To obtain infrared images, Logitech quickcam pro 4000 camera with IR 80 optical filter was used and normal LEDs were replaced by infrared LEDs. Figure 3 shows the block diagram of image processing system where all the date was processed in computer.

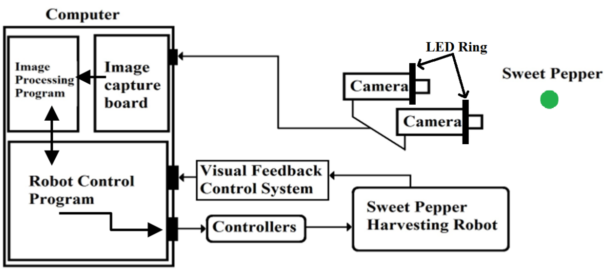

Fig.3 Block Diagram of Visual Sensing System

3.2 Color Space Models and Image Processing

At present, 5 major color space models are being used in image processing viz. CIE, RGB, YUV, HSL/HSV, and CMYK. The CIE color model attempt to produce a color space based on measurements of human color perception and it is the basis for almost all other color spaces. Based on the various parameters 6 color space models were chosen for distinction of green sweet peppers as, CieLab which is based on human eye perception, HIS and HSV which are based on hue and saturation, YIQ and YUV which are based on luminance and chrominance and grayscale for infrared images.

The lightness information from HIS, brightness information from HSV, chrominance information from YIQ and luminance information from YUV were supposed closely related to the reflection feature from image and that was the main reason for selecting these models.

Figure 4 shows the outline of the algorithm used for the color images obtained from CCD camera.

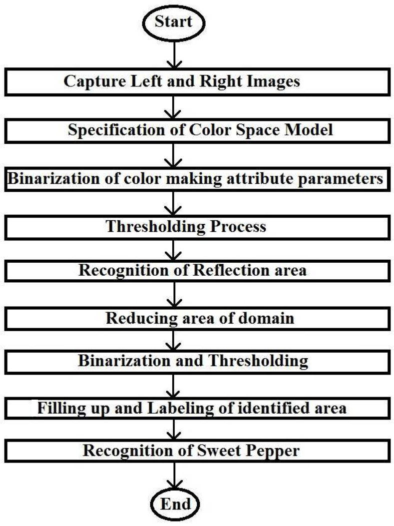

Fig.4 Image Processing Algorithm

4. Experiments

For the experiments, 6 color space models were selected for color images as

1. CieLab
2. YIQ
3. YUV
4. HSI / HSL
5. HSV
6. Grayscale (Infrared Images only)

The set of 50 images were captured using camera and LED light during night time in order to avoid the effect of sunlight. Then captured images were analyzed and processed for each color space model by using Halcon software to detect the green sweet peppers. For image processing, binarization process was done to normalize the images in various color making attributes. At this stage, threshold process was done to identify the area of interest with the help of reflection feature. Then the area of interest was reduced and again same binarization and threshold process was carried out. At this stage, again reflection feature was used to identify the green sweet pepper as these reflection areas having high brightness, high intensity and low saturation. These reflections were due to the LED lightening used along with camera which helps in distinction of target. Finally, the filling up and labeling of the identified area was done and recognition of sweet pepper accomplished with outlining the border of identified area.

In case of infrared images, the image processing was straight forward as the images were in grayscale format. The images were segmented with the help of dilation process and then threshold operation was used to detect the green sweet peppers.

Figure 5 shows the color image and infrared image captured during experiments.

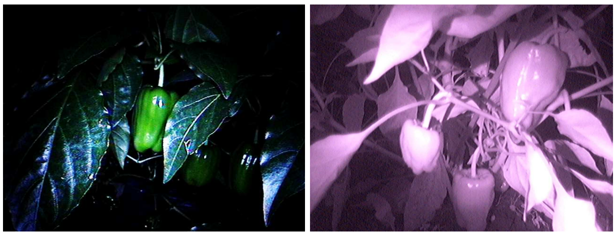

Fig.5 Captured Images: CCD camera (left), Infrared camera (right)

5. Results and Discussion

The captured images were analyzed and processed in Halcon software with the help of various color space models. The image processing by this way would help to choose the more efficient color space model for distinction of the green sweet peppers.

Figure 6 illustrates the steps involved in the image processing of images obtained by CCD camera by using HSV color space model.

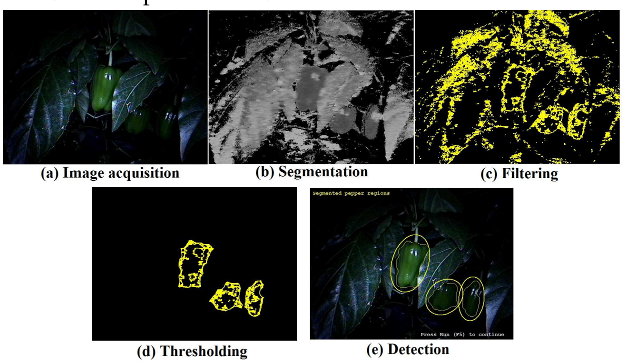

Fig.6 Image Processing Steps

5.1 CieLab Color Space Model

Though CieLab color space was designed approximate to human vision perception and having advantage of accurate color balance by using lightness, chroma and sometimes hue, this color space model was found not significant. The color space model was failed to recognize the green sweet peppers. The reason for detection failure might be the color attributes falls outside the gamut of human vision which makes the color space purely imaginary and could not be applicable for detection of green sweet pepper.

5.2 YIQ Color Space Model

In YIQ color space model, the histogram equalization was applied over Y channel and information from I channel was used for segmentation. After filtering and thresholding, the analyzed data were not enough to discriminate the green sweet peppers in all the images as YIQ color space model only help to normalize the brightness levels of the image.

In YIQ color space, the information from I channel might be highly sensitive to orange-blue than information from Q channel to purple-green. Enhancing the bandwidths for Q channel and decreasing bandwidths for I channel might help to improve the results.

5.3 YUV Color Space Model

The results obtained by YUV color space model were found almost similar to YIQ color space model. The luminance component was dominated by chrominance component which results in reduction of information on reflection feature. The U channel information was found almost negligible.

5.4 HSI/ HSL Color Space Model

The HSI color space model was found suitable to detect the green sweet peppers. The reflection feature was found easy to distinguish in H information channel. But when the sweet peppers were overlapped or covered with leaves more than 50%, then the results were unstable and detection was not correct. This problem of misdetection might be the higher intensity of chroma component in H channel which dominate lightness information from I channel.

5.5 HSV Color Space Model

The HSV color space model was found highly efficient in detection of green sweet peppers. The brightness information from V channel has a good response to chroma in H channel. The reflection feature has high brightness, high chroma and low saturation which separate the light reflected part from the image. The high LED light intensity might cause this color space model to misdetect but adopting proper light intensity this problem can be solved. If the sweet pepper covered by leaves or overlapped until 75-80%, still HSV color space model provide almost stable results.

5.6 Infrared Image Processing

The infrared images captured by using IR 80 optical filter were processed on grayscale. The detection of green sweet pepper by this filter was found not significant. The grayscale values of leaves and fruit while thresholding were found very close to the grayscale values of reflection area which indicate that IR 80 optical low band pass filter demolished the short infrared wavelengths reflected from the fruit. The detection of green sweet peppers by using IR 80 filter was found very low. The grayscale values of fruits and leaves were almost same as that of reflection which made it difficult to separate the fruits from images. The main reason for this might be the wavelength that had more information regarding reflection feature was blocked by filter which cannot differentiates fruit from leaves. So adopting infrared filter with wavelength higher than 850nm, the results could be improved.

The results obtained from various color space models can be seen in figure 7 while figure 8 shows examples of results obtained for other images. Table 1 shows the percentage of detection for each color space model from set of 50 images processed.

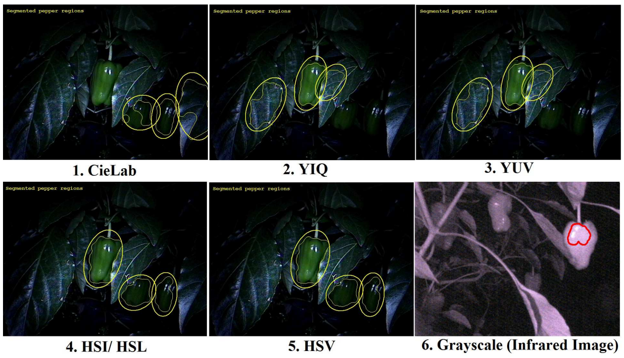

Fig.7 Various Color Space Model Results

Table 1 Percentage of Detection

Color Space Model	Detection of Green Sweet Pepper				
	Less than 25%	25–50%	51–75%	More than 75%	Failed
CieLab	26	9	2	0	13
YIQ	16	4	10	11	9
YUV	12	9	6	2	21
HSI	8	11	9	14	8
HSV	10	4	3	29	4
Infrared	15	6	1	0	28

6. Conclusions

The various color space models were tested for the detection of the green sweet peppers. In the color images, HSV color space model was found more significant with high percentage of green sweet pepper detection. In HSV model, high brightness, high chroma and low saturation which separate the light reflection part from the image was an advantageous point for discrimination of green sweet pepper. The HSV and HSI color space models were found suitable for detection as it provides information in terms of hue/lightness/chroma or hue/lightness/saturation which are often more relevant to discriminate the fruit from image at specific threshold value. The overlapped fruits or fruits covered by leaves can be detected in better was by using HSV color space model. The YIQ model could be useful for detection if the bandwidths of Q channel raised higher that dominate the effect of luminance and increase sensitivity to purple-green than bandwidths of I channel.

The IR 80 filter was found not appropriate to detect the fruits. This filter blocks the useful information and hence the complete detection was not possible. Improvement in algorithm and adoption of IR 85 to IR 97 optical filter for detection would be considered as future recommendations for research.

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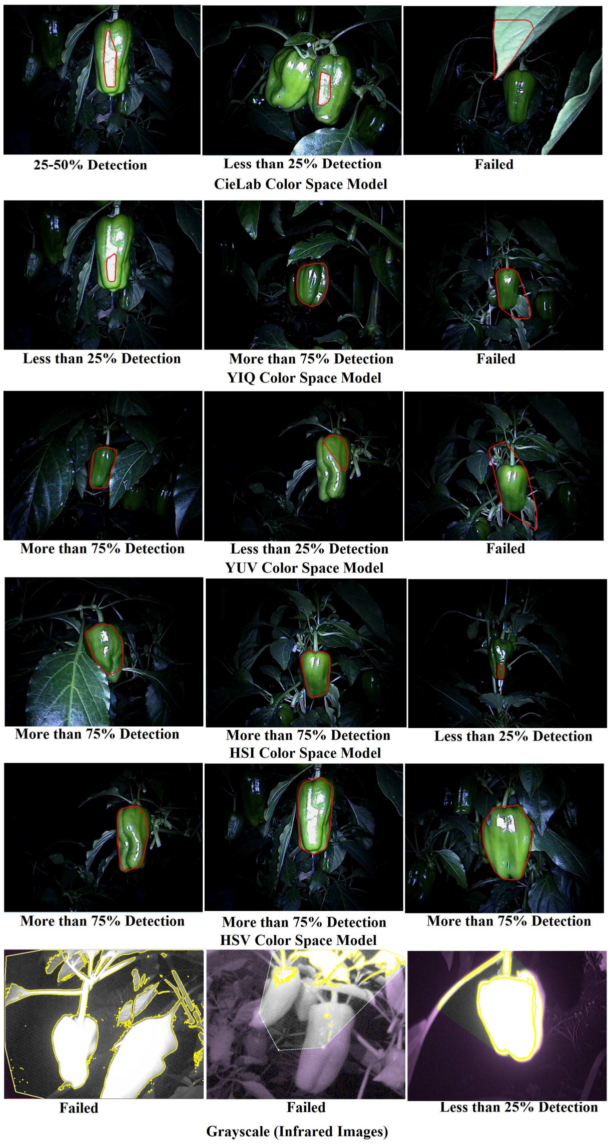

Fig.8 Examples of Results