

# OPTICAL PROPERTIES FOR MECHANICAL HARVESTING OF OIL PALM FFB

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**T**he engineering properties of agricultural materials constitute important engineering data in the design of machines to be used in harvesting. A colour camera vision system was developed to distinguish between different categories of oil palm fruit bunches. The maturity or colour ripening index was based on different colour intensity. Machine vision employs a computer and camera to analyse and interpret images equivalent to the human eye and brain. The colours namely red, green and blue (RGB) of the palm oil fruit bunch were investigated using camera vision. The specimens were captured using a CCD camera, Matrox Meteor card, and Matrox Intellicam software. The laboratory results showed that the ripe fruit bunch could be differentiated from other categories of fruit bunches based on RGB intensity. A computer program written was able to differentiate the ripe fruit bunch and send a signal to the controller to activate the machine or robot arm to carry out harvesting.

## INTRODUCTION

**A**s stated in the 'Economic Report 1998/99', palm oil production was estimated to have dropped 8% in the year 1998. In the first eight months of 1998, palm oil output declined by 8.4% to 5.29 million tonnes compared with 5.77 million tonnes for the same period of 1997. A significant decline in the output of the agriculture sector by an estimated 5.9% in 1998 was attributed to lower production. Lower production was attributed to the impact of industrialization which has caused the transfer of resources such as manpower, land and capital, out of the agricultural sector into the manufacturing sector. Then there are factors such as the lack of

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commercialization, low technology, efficiency and productivity. Mechanization or the use of new engineering technology will reduce manpower, lighten the burden, increase productivity as well as make agricultural jobs more interesting.

Recent activities in the mechanization of harvesting of agricultural products have brought about a significant reliance on the engineering properties of agricultural materials. Knowledge of the engineering properties of agricultural materials should be of value not only to the engineers, but also to food technologists and scientists, who may find new uses for these products (Wan Ishak et al., 1997). Colour is one of the most significant inspection criterion related to fruit identification and fruit quality to indicate maturity.

Vision is the most powerful sense. It provides us with a remarkable amount of information of our surroundings and enables us to interact intelligently with the environment. Vision is also one of the most complicated senses. With the application of modern technology, machines with a sense of vision are widely used in the industrial sector. In the industrial sector, vision systems are used under working environment that can be controlled. Vision systems are used to detect products, for quality control purposes by their shapes and patterns. Machine vision is a technology that employs a computer and video camera to analyse and interpret images in a manner resembling human vision. The camera is equivalent to the human eye and the computer is equivalent to the human brain.

Vision systems are a new field of research in the agricultural sector. Knowledge on how biological vision systems operate is directly concerned with signals from the sensors. In agricultural applications, especially for fruit handling, we cannot detect fruit quality just by its shape or pattern. This is because a fruit may have a different shape and pattern but the same level of quality. To solve this problem, the vision system should be able to analyse the colour of the object or fruit. In the harvesting and picking of oil palm fresh fruit bunches (FFB) in the field, a combination of shape, pattern and colour analysis in a vision system must be applied.

This paper investigates the use of a machine vision system to identify the object (i.e. oil palm fruit bunch) by colour and send the signal to enable the robot to pick the object. This project employs a vision system to differentiate and

analyse the colours between the oil palm fruit bunches and between the colours of the oil palm bunch with the other objects available in the oil palm plantation. The objective of this project was also to develop a computer program to process the data related to the colour of the fruit. For processing the data and frame grabbing, a Pentium machine of **166MHz**, Sony CCD RGB camera, Matrox Meteor board, Matrox Intellicam and Matrox Inspector were used. The camera was used to grab images of interest and the Matrox Meteor board was used to receive the signal from the camera. The Matrox Intellicam software was used to grab or capture images and the Matrox Inspector analysed the colour of the image file. The C++ programming language was used to write program to differentiate the colours and signals to the robot arm. *Figure 1* shows the block diagram of the hardware system, *Figure 2* shows the integration of the software and *Figure 3* shows the experimental steps.

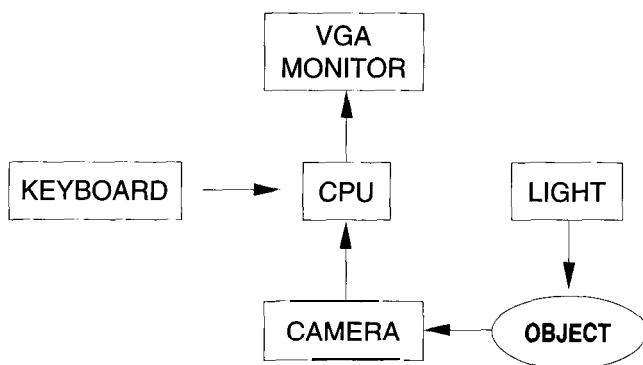


Figure 1. The block diagram of hardware system.

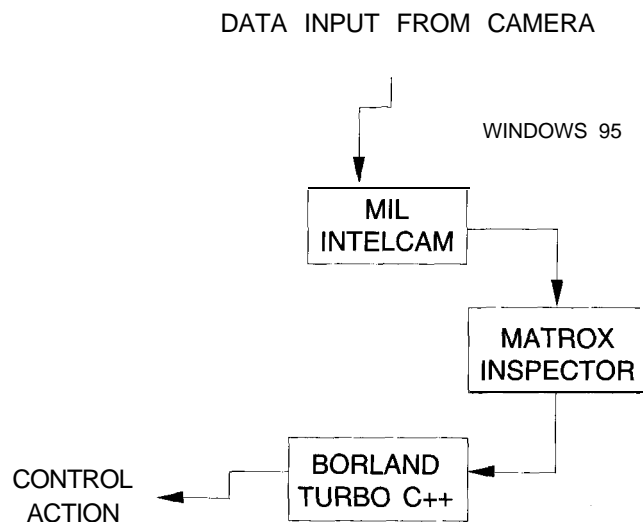


Figure 2. Integration of software.

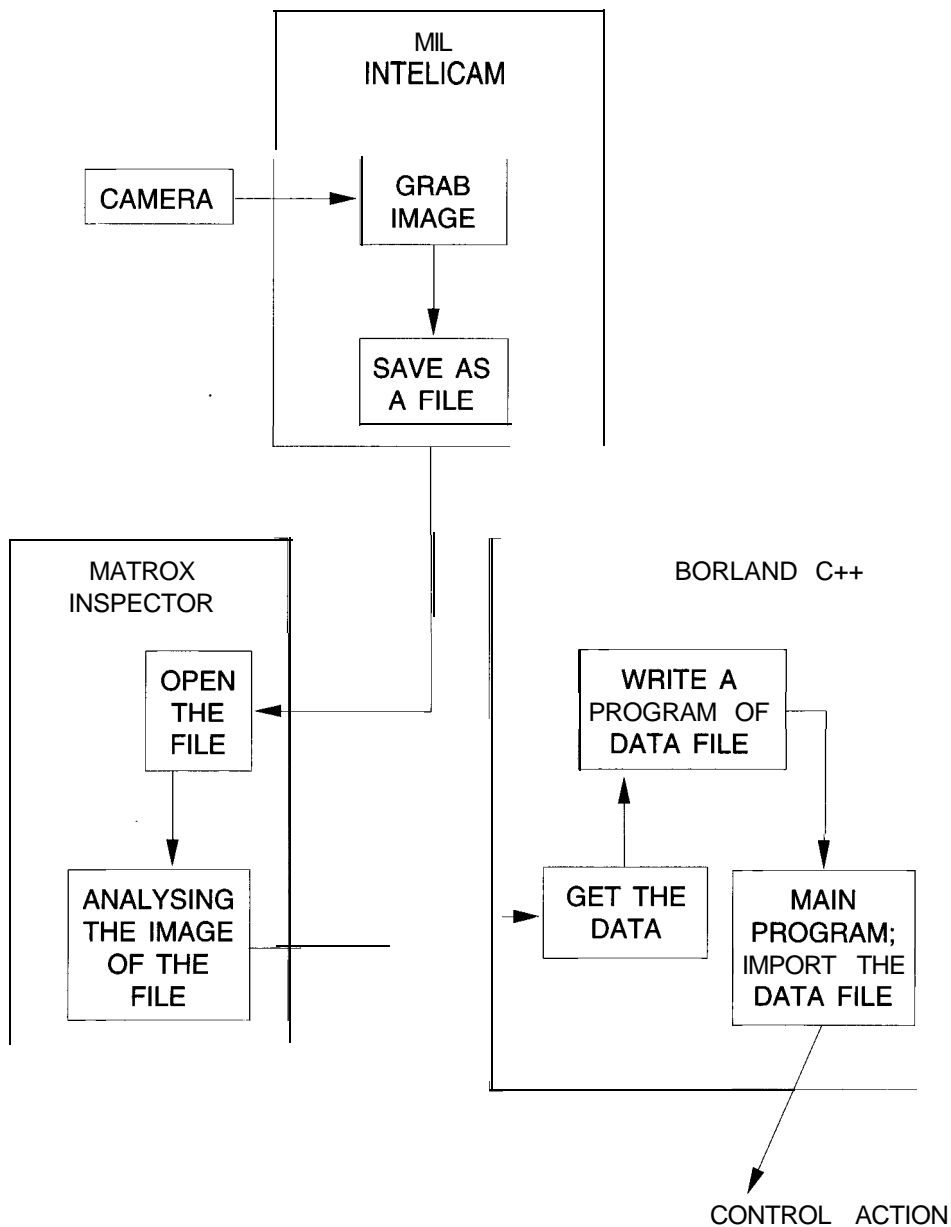


Figure 3. Experimental steps.

### LITERATURE REVIEW

Machine vision is concerned with the sensing of images and its interpretation by computer. A typical vision system uses a camera to identify the object and software to analyse the object. Machine vision has emerged as one of the most important new technologies in industry as it reduces production costs and improves product quality by enabling accurate inspection of products.

In agro-based industries, researchers have used digital image analysis for bruised fruit detection. Tao et al. (1995) used digital image analysis and machine vision for apple and potato colour inspection. Computer vision systems for evaluating the quality of fresh market tomatoes were reported by Sarkar and Wolfe (1985). Peach grading using a colour vision system was reported by Byron et al. (1989). The basis of colour for an object is its spectral reflectance curve, showing surface reflectance as a function of

wavelength. Wan Ishak (1976) determined the spectral reflectance characteristics of pepper, and discussed the results with respect to automatic sorting of pepper by a light reflectance technique. In order to use the reflectance technique for sorting pepper, there must be a difference in the reflectance response from the fruit at a particular wavelength or combination of wavelengths.

For the past few years, machine vision applications for automated inspection and sorting of fruits and vegetables have been studied and reported. Colour vision systems have been found more effective in colour inspection than monochrome systems. A colour camera output can be decoded into three images to represent the RGB components of the full image. The three components of the colour image can be recombined in software or hardware to produce intensity, saturation and hue images which can be more convenient for subsequent processing. In computer, the intensity of the colours is based on bits. It is **24-bit** colour (**8-bits** red, **8-bits** green and **8-bits** blue), each representing a non-normalized RGB co-ordinate with a decimal value from 0 to 255.

There are many techniques developed in the field of machine vision. Among them are image processing, pattern recognition, scene analysis and artificial intelligence. Image processing is largely concerned with the generation of new images from 'existing images. The new image may have noise suppressed, blurring removed or edges accentuated. Pattern classification is the classification of a pattern given as a set of numbers representing the measurements of an object. Scene analysis is concerned with the transformation of simple description, obtained directly from images, into more elaborates ones, in a form more useful for a particular task. Artificial intelligence is used to analyse scenes by computing a symbolic representation **of the** scene contents after the images have been processed to obtain features.

## METHODOLOGY

The instrumentation for the vision system can be divided into hardware and software. The hardware consisted of a camera, computer and Matrox Meteor board. The Sony CCD RGB single chip

camera was used to grab images of interest. The Intel Pentium 166MHz processor with memory of 16 Mbytes RAM was used to process the data and the Matrox Meteor board was used to receive the signal from the camera.

The software consisted of Matrox Intellicam, Matrox Inspector, Borland Turbo C++ and Windows 95. Matrox Intellicam 2.0 provided the camera interfacing and interacting access to all the grab features and functionality of the Matrox the digitizer. The Matrox Inspector 1.7 software was used for analysis of the colour of the image. In analysing images, Matrox Inspector provided a very useful menu that allowed us to extract the components of colour, analyse the images in monochrome, RGB and HSL (hue, saturation and luminance) format. The Turbo C++ programming language was used to write a program for colour analysis and gave the colour indexes resulting from the images.

In this project, a computer program was written to analyse the RGB and HSL data of the images. The computer program used the average colour intensity to differentiate between the different colours or ripeness of the fruits, i.e. oil palm FFB. When the camera views the object, the Matrox Intellicam grabbed the image of the object, and saved it in the CPU. The Matrox Inspector analysed the intensity of RGB colours of the image and saved. This data will then be compiled in the C++ program to determine the colour index of the image.

In this project, a computer program was also written to differentiate the 'ripe' category from other fruit categories. The program used a command to produce the output of electrical signal through the parallel port or printer port of the computer. When the program detected the RGB properties of the image matching the data that was used as reference, the corresponding LED (light emitter diode) will turn on. This signal can be used to turn on a switch to activate a machine or robot arm to harvest oil palm.

The colour of oil palm FFB was classified as black, hard, ripe, over ripe, empty bunch and rotten. This classification was taken from **Kulumpang Development Corporation Sdn. Bhd.** standard, which was based on PORIM (now known as **MPOB**) standards. The descriptions of the classifications were shown in *Table 1*. The samples were shown in *Figures 4, 5, 6, 7, 8,* and 9.

**TABLE 1. CLASSIFICATION OF OIL PALM FRUIT BUNCH**

Category	Description
Black	Bunch with complete fruits
Hard	Bunch with 1 to 9 fruits detached
Ripe	Bunch with 10% to 50% fruits detached
Over ripe	Bunch with 50% to 90% fruits detached
Empty bunch	Bunch with more than 90% fruits detached
Rotten	Bunch with all or part having turned black with or without fungal attack



Figure 4. 'Black' bunch.

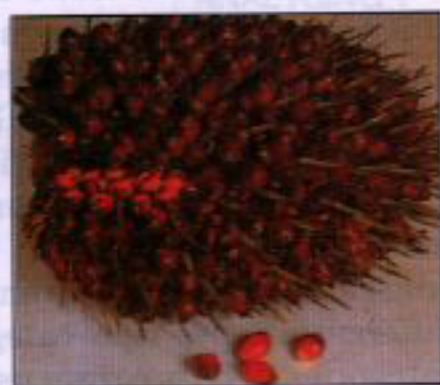


Figure 5. 'Hard' bunch .



Figure 6. 'Ripe' bunch .



Figure 7. 'Over ripe' bunch.



Figure 8. 'Empty' bunch .



Figure 9. 'Rotten' bunch .

Ten samples of oil palm FFB were taken for analysis. The fruits were placed vertically under the camera. The distance of the camera to the floor was about 1 m. Data of the colour taken from an image was represented by drawing horizontal and vertical lines, as indicated by the positions in Figures 10 and 11. These lines represented the colour of the whole fruit. In the analysis, the result was represented by the graph to show the difference between the RGB. The percentage difference equation for each particular colour is as below:

$$\% \text{ Difference of } a = \frac{(\text{Intensity of } a - \text{Intensity of } b) \times 100}{\text{Intensity of } a}$$

where *a* and *b* are the colours of RGB.

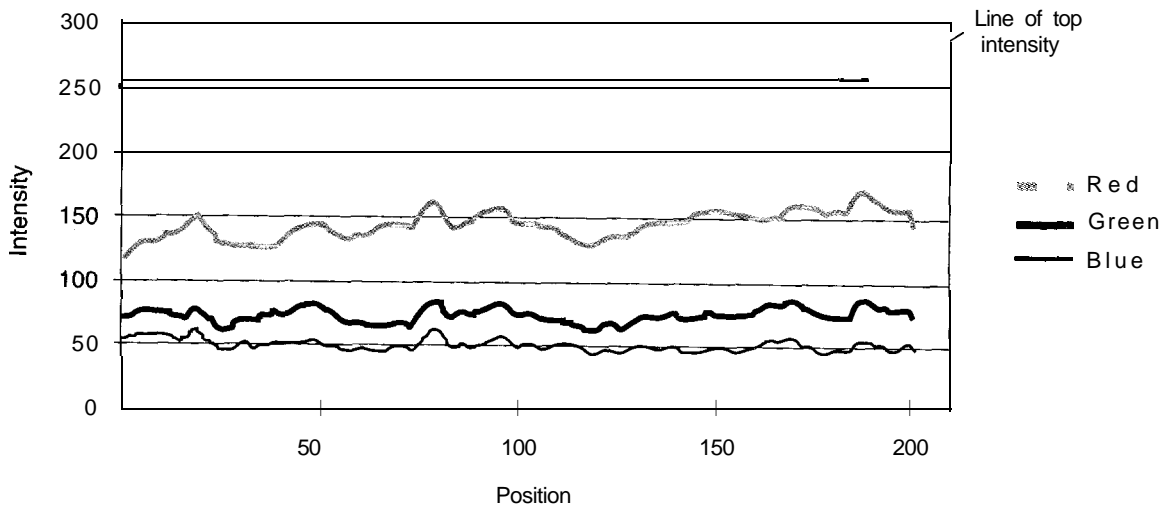


Figure 10. Graph of RGB for oil palm 'ripe' fruit bunch.

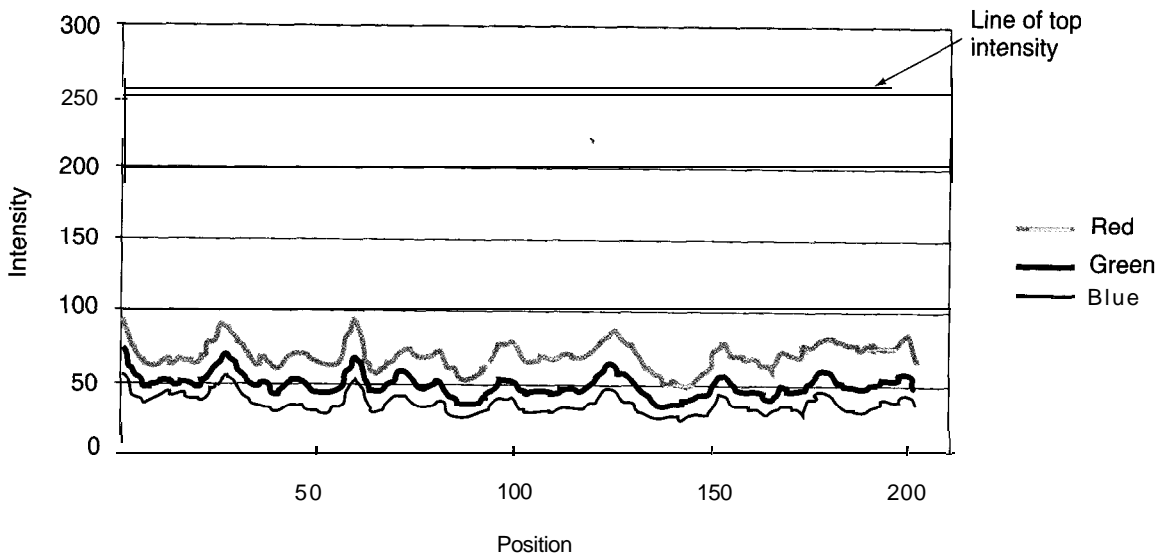


Figure 11. Graph of RGB for oil palm 'empty' fruit bunch.

**RESULTS AND DISCUSSIONS**

The colours of oil palm fruit bunches were analysed based on their maturity. The categories of the maturity were described earlier and shown in Table 1. Table 2 shows the average RGB for each category of the oil palm fruit bunch maturity. Table 3 shows the RGB percentage difference between red and green, red and blue, and green and blue for each category of maturity. Table 4 shows the range of RGB intensity of the oil palm fruit bunches.

**TABLE 2. AVERAGE OF RGB INTENSITY OF THE SPECIMENS**

Category	Average of RGB (decimal value)		
	Red	Green	Blue
Black	65.1	54.8	50.2
Hard	99.6	62.0	51.0
Ripe	144.5	73.3	50.4
Over ripe	107.0	61.0	44.0
Empty	71.5	51.6	38.8
Rotten	83.3	61.5	46.6

**TABLE 3. THE PERCENTAGE RGB INTENSITY DIFFERENCE OF THE SPECIMENS**

Category	RGB percentage difference (decimal)		
	Red-green	Red-blue	Green-blue
Black	15.8	22.9	8.4
Hard	42.0	52.3	17.8
Ripe	49.4	65.1	31.2
Over ripe	43.4	59.1	27.6
Empty	27.8	45.7	24.8
Rotten	26.6	44.2	24.2

**TABLE 4. THE RANGE OF RGB INTENSITY OF THE SPECIMENS**

Category	RGB intensity range (decimal)		
	Red	Green	Blue
Black	52.6 - 77.6	48.0 - 61.5	45.3-51.2
Hard	95.3 - 107.3	52.7 - 63.8	42.4 - 53.6
Ripe	113.5 - 178.0	53.8 - 94.3	40.5 - 64.2
Over ripe	97.3 - 125.9	51.4 - 65.9	33.2 - 50.3
Empty	61.5 - 82.3	47.1 - 57.4	36.2 - 41.6
Rotten	60.0 - 84.7	42.0 - 61.5	33.0 - 46.7

A mature oil palm FFB, ready to be harvested, was categorized as 'ripe' fruit bunch. A mature oil palm is reddish in colour that gives a high intensity of red colours compared to the other two colours, namely, green and blue. **Table 2** shows that the average intensity of RGB colours were **144.5, 73.3** and 50.4 respectively. The colour range of RGB intensity for the 'ripe' fruit bunch were 113.5 to **178.0, 53.8** to 94.3 and 40.5 to 64.2 for red, green and blue respectively. The RGB percentage differences calculated for red compared to green, red compared to blue and green compared to blue were **49.4%**, 65.1% and 31.2% respectively. **Figures 10** and **11** show an example of the intensity graph of RGB for a 'ripe' fruit bunch, and an 'empty' fruit bunch respectively.

The average RGB, RGB percentage difference between the colours of oil palm FFB and range of RGB intensity are shown in **Tables 2, 3** and **4** for the respective black, hard, over ripe, empty bunch and rotten categories of oil palm FFB. It is important to compare the colour properties of the 'ripe' fruit bunch with the other categories of fruit bunches in order to differentiate the differences of the RGB.

The average intensity of red colour for the 'ripe' differed from 'black', 'hard', 'over ripe', 'empty' and 'rotten' by **79.4, 44.9, 37.5**, 73.0 and 61.2 respectively. From **Table 4**, we can see that the ranges of colour intensity for all categories of oil palm FFB were almost the same. These values showed that the 'ripe' can be differentiated from other categories by using average intensity and cannot be differentiated using the range of colour intensity.

The average intensity of green colour for 'ripe' differed from 'black', 'hard', 'over ripe', 'empty' and 'rotten' by 18.5, 11.3, **12.3, 21.7** and 11.8 respectively. The average intensity of blue colour for 'ripe' differed to 'black', 'hard', 'over ripe', 'empty' and 'rotten' by 0.2, 0.6, **6.4, 11.6** and 3.8 respectively. From the above values, only the 'empty' can be differentiated from the 'ripe' using the average green colour intensity. We cannot differentiate the 'ripe' from other categories of oil palm FFB using the average blue colour intensity.

The computer program used the average colour intensity to differentiate the ripe category from the other fruit categories. Two LED were connected to the parallel port of the computer to receive the electrical signals produced by the colour images of the fruit bunches. LED 1 was used for 'ripe' and LED 2 was used for the other categories. The computer program written in C++ language was combined with MIL commands to grab the image and immediately analyse the image. The average colour intensity for all the fruit categories was saved. The program also saved the red colour of the 'ripe' fruit bunch to be used as the reference point. When the program detected the RGB properties of an image that matched with the data that was used as reference, the corresponding LED will automatically be switched on. The experiment carried out, showed that when the camera detected a 'ripe' fruit bunch, it gave the average red colour intensity that matched with the reference red colour intensity already installed in the computer. LED 1 was turned on. This signal can be used to turn on a switch to activate the harvester or robot arm to harvest the oil palm FFB.

## CONCLUSION

This project was conducted to determine and differentiate between the colour properties of oil

palm fruit bunch. The camera vision system was able to detect and differentiate the ripe oil palm FFB from the other categories of oil palm FFB. A computer program developed was able to send a signal to the parallel port or printer port of the computer. The signal, in the form of electrical pulse, was used to turn on the LED that was attached to the port. The signal can be used to turn on a switch to activate the harvester.

This initial study was only carried out in the laboratory environment under controlled conditions. The distances between the camera and the object and source of lights were made constant. In the future, the experiment should be conducted in the field for the real environment. The analysis of the colour should include and consider the intensity of light, which changes almost all the time.

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