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Highly Efficient Fruit Mass and Size Estimation Using Only Top View Images †

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Abstract: This paper presents a new methodology for the estimation of mass and size of a common Vietnamese fruit, cavendish-type banana. We only used top-view images. Most previous works focused on volume estimation using a plurality of cameras to infer the three-dimensional information. In this work, we only use a single camera mounted on top of the fruit. We have found that our proposal lead to a relatively small estimation error (approximately 6%) compared to the results obtained from the measurements using a water-displacement method and a static digital scale. The results indicate that our system shows a great potential to be used in a real industrial setting. Future work will aim to investigate other features such as ripeness and bruises to increase the effectiveness and practicality of the system.

Keywords: machine vision; mass estimation; image processing; volume estimation; water displacement method.

1. Introduction

According to Statista [1], bananas were the second place among the global fruit production in 2017. It contains carbohydrate, protein, and variety of minerals and vitamins. Its physical properties have been being researched in order to get the highest value of each banana that can release to the market.

Tropical countries which have the high value of banana are receiving the escalator orders, especially Vietnam. Laba banana in Vietnam is a part of Musaceae family which is a subgroup of Cavendish banana. Every year, Vietnam export billion tons of bananas to Japan, China, Malaysia and South Korea. Recently, this country receives high reputation and gets many orders from EU countries, Russia, and Qatar.

There were some researches on banana with its physical properties, such as Ahmad et al (2001) Ahmad et al. showed how the temperature make an impact on the ripening of banana fruit [2], Mendoza et al. classified the maturity phases of bananas by image processing method [3], or applying gas sensors to detect whether the banana is ripe or not [4]. Similarly, with other fruits such as strawberry [5], kiwi fruit [6], coconut [7], melon [8], and mango [9,10]. Moreover, sorting and measuring the weight and volume of food is still one of the problems that human being is facing. One of the most accuracy method is using a digital caliper and water displacement method. However, those methods are too slow and unproductive when applying to the industry.

M. Omid et al. developed a system that equips 2 CCD cameras placing 2 side of the citrus fruits [11]. After that, they used segmentation method and divided citrus fruit into frustums. Finally, they estimate the volume by summing all the approximate frustums. Li and Zhu sorted apples by measuring the diameter with feature fusion of size, shape, and color [12]. Those studies focused on objects that are round or nearing ellipse shapes, while banana is more complicate due to its shape. However, M. Soltani et al. also shows the way to estimate the volume V_{ellip} and the surface area S of the banana [13]. They slice the banana into small parts and sum calculated S and V_{ellip} of each part to get the estimation.

Machine vision plays an important role on the food industry and agriculture in recent years. It is embedded into the production line in order to sort the product, check the quality standard, etc. However, those existing methods are still complicated and costly. In this paper, we propose a new method similar to [11] but this system requires only one camera that capture the top projected image of the fruit. With only simple calculations, we can estimate the volume and weight of banana fruit with high accuracy.

2. Experiment setup

Our setup consists of one camera mounted on a frame located on top of a banana. An A4-sized paper is placed underneath the banana to be used as a guide for calibrating our system. In addition, we placed four light sources around the banana to get rid of shadows as shown in Figure 1. Next, we crop the images to the extent of the A4-paper to ease the background segmentation. Then, from the segmented images, we can estimate several size-related parameters for each banana, such as: length, width, perimeter, top view areas and so on.

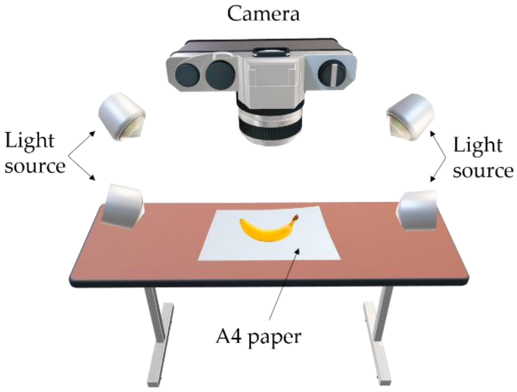

Figure 1. Our experiment set-up

We measure widths, heights and weights of all the banana samples to use as ground truths for further comparison and estimation. The measurement tools comprised of a digital caliper and a digital scale respectively. The water displacement method was also applied to measure the bananas' volumes.

Since we only capture top-view images, some important parameters are missing, the side-view information of the bananas. We decide to formulate some experimental relationships for the depth parts. We have collected many thin slices taken in the direction that is perpendicular to the top view plane. Figure 2 shows that the cross-sections are not circular. With over 200 test samples, we conclude that the width of the banana always larger than its height, the average ratio h/w is about 0.956.

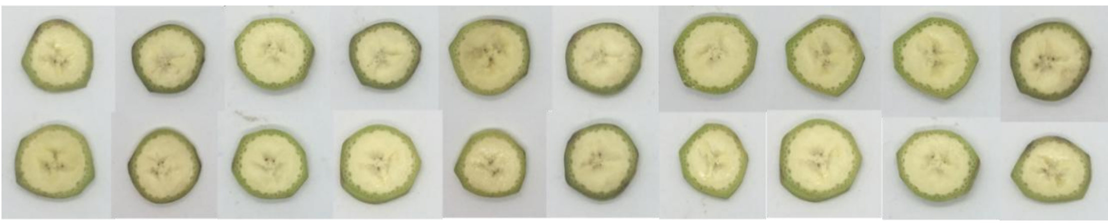

Figure 2. Some examples of cross-sections of banana slices.

After converting the top view images into grayscale, we use a traditional Otsu thresholding scheme for the GREEN channel of the images. We divided bananas into two parts. The first part consists of the top and the end of the banana and the second part is the middle of the banana as shown in Figure 3.

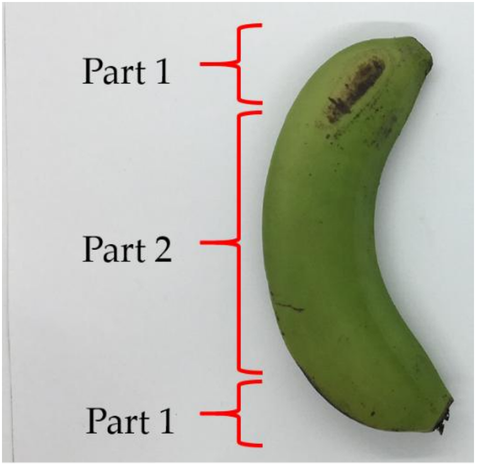

Figure 3. Two major parts of banana divided by our system.

We decide to use part one length is one fifth of the total length.

To estimate the volume of part 1, we assumed it to be an elliptical cone and applied the necessary volume calculation formula from [14] (see figure 4).

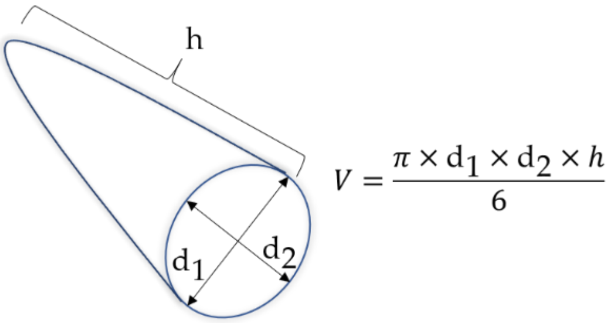

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Figure 4. Formula for calculating the volume of an elliptical cone [14]

For part 2, we divided it into small parallel slices. And each slice's volume is estimated as a volume of a frustrum (see Figure 5 - 6):

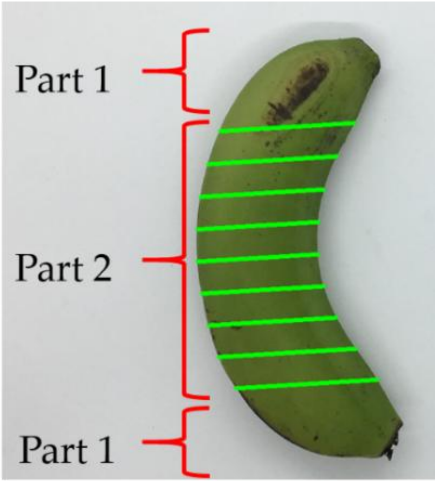

Figure 5. Part 2 was divided into many small parallel slices.

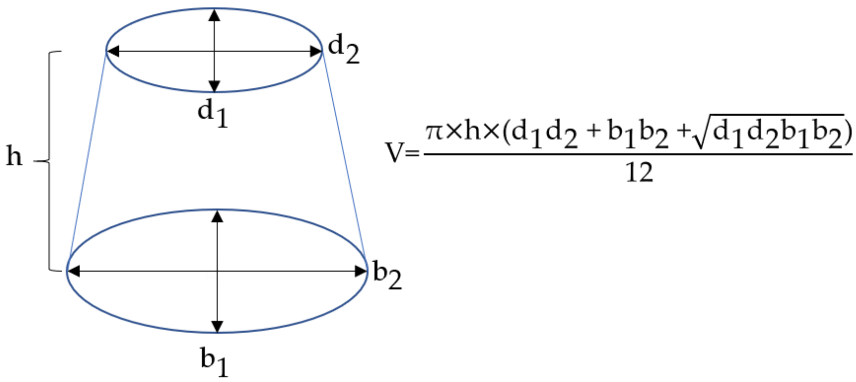

Figure 6. Formula for calculating the volume of a frustrum [14].

3. Results

3.1. Volume estimation result

Due to the width and height of cross section are not the same as shown previously in Section 2, we have to apply a correction ratio for the volume calculated for the elliptical cone and the frustrums by the h/w ratio which is 0.956. Finally, the total volume of the banana is the sum of the volumes of part one and part two.

We have tested with a data set of 56 bananas.

For part two, we want to investigate the number of thin slices necessary to give satisfactory results. We tested with four cases of 4, 8, 12 and 16 slices. The comparison is shown in table 1.

Table 1. Percentages error of total volume of banana when Part 2 had different sliced.

Number of Slice	4 Slices	8 Slices	12 Slices	16 Slices
Average errors of all 56 bananas (%)	6.05	5.71	5.74	5.73

As in the result, 8 Slices will be the best option for our case.

Figure 7 shows the average error for volume estimation based on our approach compared to actual volume obtained from the water displacement method. Average error is only about 7% for 56 test samples.

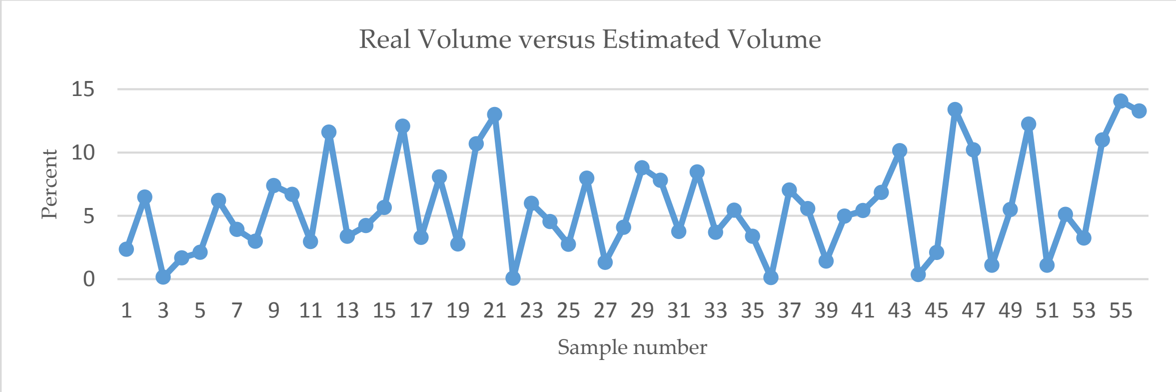

Figure 7. Relative error in volume estimation.

3.2. Mass estimation result

With real value of mass and volume of bananas, we got the average of all banana's density is 0.9183 (a.u). From that, we can estimate the banana's weight by using the product of the estimated volume and the average bananas' density. The weight estimation error is shown in Figure 8.

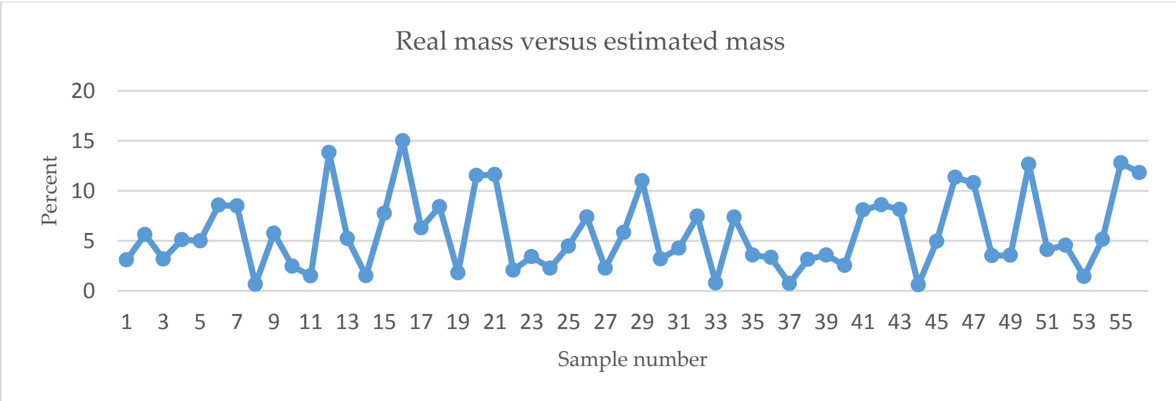

Figure 8. Relative error in mass estimation.

3.3. Computational expense

The hardware that we used for this experiment was Dell 5558 with Intel Core i7-5500U (2.4Ghz). The Python and OpenCV Library are used extensively in this project. We also recorded the processing time for all of the samples (56 pictures), each with 100 repetitions. The outcome is shown in the following table.

Table 2. Processing time.

Max processing time for 56 pics (sec)	Min processing time for 56 pics (sec)	Average processing time for 1 pic (sec)
4.268451297	3.669792497	0.06 - 0.07

4. Conclusion

In machine vision, 3D image of fruits will solve all the problems of 1D image (measuring height) and 2D image (surface area). However, with 3D image, we need a 3D camera, or many cameras projected around the object. In addition, a powerful computing hardware is also needed in order to calculate all the features of each object such as Savan Dhameliya et al. sets up a system that contains 5 cameras to estimate the surface area and projected area of the mango in digital images [15]. This paper shows that with only a single camera, we can estimate the size, volume, and mass of a Laba banana. Furthermore, the computational steps contain only some geometric formulas. Those make this system's requirement is low cost, fast, and high accuracy from 94% to 95%. In the future, we want to make a portable version of the high dynamic range imaging system as in [16,17] so that we can capture and evaluate the banana on the field.

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