Automatic dragon fruit counting using adaptive thresholds for image segmentation and shape analysis

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***Abstract*— In recent years there have been many proposals for automated applications in vegetable harvesting. There are two major challenges: estimation of yield and harvesting of fruit trees. This research proposes a new algorithm that allows accurate counting of the number of fruits on a tree to accurately estimate the output of a dragon fruit. The algorithm consists of the following main steps: image segmentation, boundary determination, shape analysis, and overlap analysis to count the number of dragon fruits per tree. Experimental results show that the algorithm can solve the problem of counting the correct number of fruits per tree to accurately estimate the yield of dragon fruit in the farm.**

Keywords—Automatic fruit counting, Color space, Image segmentation, Shape analysis, Size estimation, Identification of oversegmentation.

I. Introduction

Recently, image processing techiniques are the important tools that have been widely applied in different fields, especially agriculture automation. The image processing in agriculture has been widely applied in the classification, identification and product estimation. These systems are being developed and applied in a lots developed countries around the world [1-5]. The application of science and technology in agriculture, improve the efficiency and quality of agriculture to help farmers control the management of farming activities

In agriculture, the farm produce estimation is the important part in the harvest process The disadvantages of the traditional estimation methods are time-consuming and a lot of man power. Many recently image processing techniques could improve the farm produce estimation accurate and quick.

Considering some practical requirements in this area, the authors found that the development of an image processing algorithm to solve the problem of the productivity of agricultural products estimation is very necessary. Because in fact, the process of buying and selling agricultural products is done manually. The trader with the farmer come to the farm to estimate the output of agricultural product and negotiate prices based on experience and manual. This problem sometimes causes disagreement between buyers and sellers. Therefore, An automated estimating system for agricultural products will help solve this problem. To understand the information that exists in the image, the feature extraction and the object identification are the major problems in image processing techniques. This problem is mainly based on the color and shape of the dragon fruit. Object-recognition methods, including simple algorithms, allow for the identification of discrete, discrete dragons, to complex algorithms for separating overlapping areas [6-9]. The process of counting the number of dragon fruits in a tree consists of the following steps: collecting, defining images, segmentation, shape analysis, estimating sizes, identifying overlaps and counting the number of fruits per tree as Fig. 1.

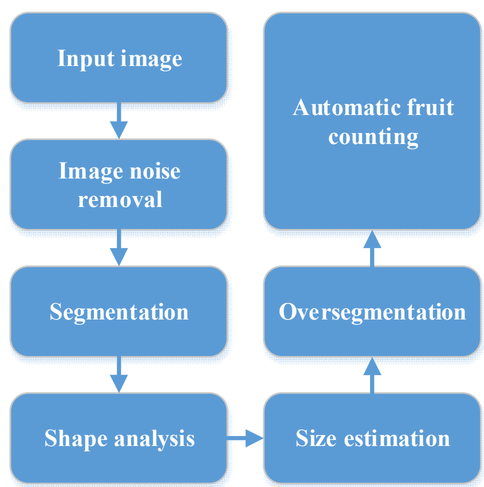


Fig. 1 Overview block diagram of the project

II. PROPOSED METHOD

A. Image processing acquisition and image noise removal

1) Image acquisition method

The input image collection process is very important in image processing. Firstly, the distance between the camera and the dragon fruit should be considered, so that the size of the dragon fruit in many images is the same. In addition, the images must be taken under the same lighting conditions. Because the light source has a great influence on the outcome of the image segmentation process. All images of dragon fruit in the project are taken from the internet for the experimental image. However, these images are taken from different angles, distances and sources. Therefore, the project should have a method to handle well on this data base.

2) Image noise removal

Image interference processing is one of the algorithms that determine the failure of the algorithm. Therefore, the selection of the appropriate filter must be determined first.

Smoothing filters are used to reduce interference and to dim the effects in the input image. Small details and boundary distortions are often eliminated in the process. After testing on the computer, a 3x3 Gaussian filter was used to eliminate input noise during image processing.

B. Image segmentation

Image segmentation is the process of dividing images into segments to identify the characteristics of the object of interest. There are a number of techniques and algorithms to apply to image segmentation processes such as thresholds, clusters, edge detection, histogram charts, etc. In this study, used. During image segmentation, there are two important steps: selecting the color space and defining the thresholding algorithm for segmentation.

1) Color space

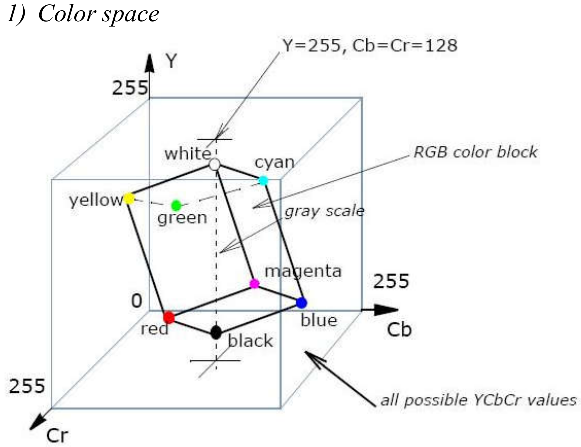


Fig. 2 YCbCr color space representation

The YCbCr color space (Fig.2) is used in the ITU-R BT.605-5 and ITU-R BT.709-5 television sector [6]. The YCbCr color space is expressed as the brightness component (Y), the blue component (Cb), and the red component (Cr). YCbCr color space is developed based on human vision. The human eye is more sensitive to the light intensity component and less to the color component. The YCbCr color space works based on this attribute to achieve high efficiency. Therefore, that is why the YCbCr color space was chosen for the segmentation process in this study.

2) Otsu algorithm

The Otsu algorithm [10] was launched by Nobyuki Otsu in 1979. The objective of the algorithm is a threshold T, which is calculated automatically based on grayscale values of the pixels in order to replace the use of fixed segment in the problem binary image based on threshold grayscale.

The basic content of the method is described as follows: First, convert the input images to grayscale images and statistics on the number of gray levels, assuming there is L $(0 \leq L \leq 255)$ grayscale in the image. We dichotomize the pixels into two classes C_1 and C_2 (background and objects, or vice versa) by a threshold at level T; C_1 denotes pixels with levels $[1..T]$, and C_1 denotes pixels with levels $[T+1..L]$.Total number of pixels is called N, $h[i]$ number of pixels in the gray level i $(0 \leq i \leq 255)$ and probability of appearance grayscale level i is: $p_i = \frac{h[i]}{N}$. From that, we calculate the optimal threshold T* by the formula (1).

$$T^* = \underset{0 \leq T < L}{Arg\,Max}\left\{\sigma_B^2(T)\right\} \tag{1}$$

$\sigma_B^2(T)$ is identified by formula from (2)~(6).

Variance:

$$\sigma_B^2(T) = \omega_1(T)\omega_2(T)\left(\mu_2(T) - \mu_2(T)\right)^2 \tag{2}$$

Probability appears of C_1:

$$\omega_1(T) = P_1 = \sum_{i=0}^{T-1} p_i \tag{3}$$

Probability appears of C_2:

$$\omega_2(T) = P_2 = \sum_{i=T}^{L-1} p_i = 1 - P_1 \tag{4}$$

The average gray level of C_1:

$$\mu_1(T) = \sum_{i=0}^{T-1} iP(i/C_1) = \sum_{i=0}^{T-1} ip_i / \omega_1(T) \tag{5}$$

The average gray level of C_2:

$$\mu_2(T) = \sum_{i=T}^{L-1} iP(i/C_2) = \sum_{i=T}^{L-1} ip_i / \omega_2(T) \tag{6}$$

The Otsu algorithm is one of the image segmentation method which is the simple algorithm to compute the threshold *T* in order to solve the global threshold. Therefore, *T* is the important factor that decises success or failure of this algorithm. Fig. 3 (c) shows that the *T* threshold is easily determined by calculating the mean value on the histogram. The region to the right of the threshold *T* is the area of the object, while the area to the left of the threshold *T* is the background.

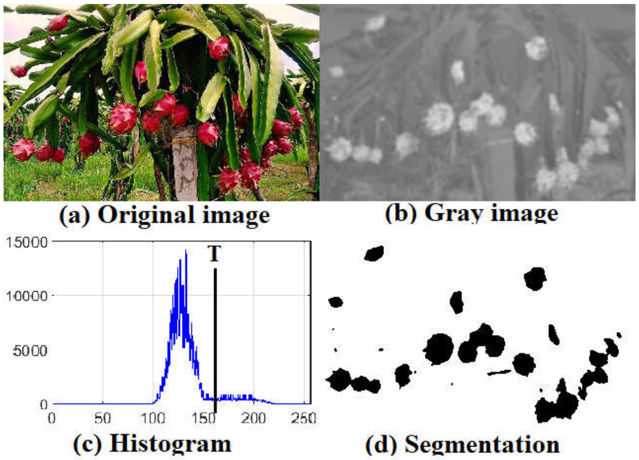


Fig. 3 The results of images segmentation by Otsu algorithm

3) Find Contours

After separating the object of the dragon fruit from the background, we will enclose the object area and draw a boundary by the contours method [11], which routes the object around the binary object and saves the boundary. This into a vector is the point lying on that boundary.

The binary image obtained at the stage of the image segment was filtered using a 5x5 Median filter to eliminate noise. Next, we use the findContours () function in the OpenCV library to detect the edges of the objects in the image.

C. *Shape analysis*

Shape analysis is the analysing the geometric shape of the segmented region of interest; in this project ,the roundness analysis is used to increase the accuracy of the object detection. The area and perimeter of each segmented region will be estimated. The boundary coordinate is used to estimate the area and perimeter of the segmented regions using morphological functions with the extracted boundary [12].

The rounded value of the segmented regions is obtained by applying the formula (7).

$$R = \frac{4\pi A}{p^2} \tag{7}$$

where,

R roundness of the segmented region

A area of the segmented region

p perimeter of the segmented region

The rounded value is equal to 1 for a circle and its value less than 1 for any other shape. From trial and error, the roundness value between 0.6 and 0.8 will be as one fruit as shown Fig. 4. For the segmented regions having the rounded value from 0.3 to 0.6 mostly are the occluded or overlapped. However, the roundness value of the dragon fruit is not enough data to determine the number of dragon fruit accurately. Therefore, the study needs to take some additional steps to determine the segments that have left many areas of dragon fruit or obscured.

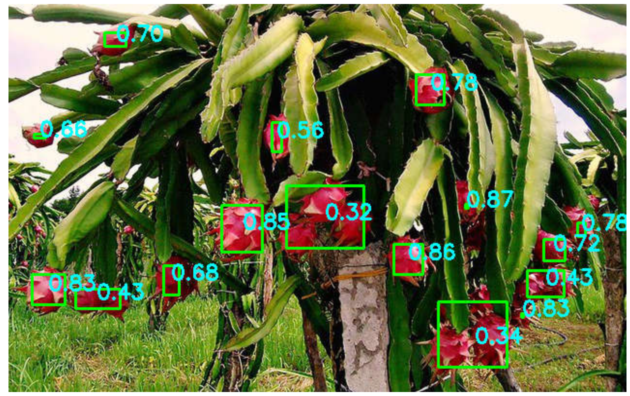


Fig. 4 The results of roundness value using shape analysis

D. *Size estimation*

The segmentation region size is estimated through the perimeter and the rounded value of that segmentation region. The segments of single fruit having the rounded value from 0.6 to 0.85. For the segmented regions having the rounded value from 0.3 to 0.6 mostly are the occluded or overlapped (Fig.5). The perimeter value of this step compares with an average value of the perimeter, the average value of the perimeter is calculated according to the formula (8). If the perimeter value is smaller than the average value of the perimeter will be as occluded by the formula (10). In contrast, If the perimeter value is larger than the average value of the perimeter will be an overlap by the formula (9). This method, We filter out the single dragon is obscured and identify oversegments has much fruit is shown in Fig. 6. Therefore, in this stage, we have not determined the exact number of dragon fruit in the overlapping regions. These overlapping to be separated into individual left in the next process.

$$p_T = \frac{1}{n}\sum_{i=0}^{n} p(i) \tag{8}$$

where,

p_T average value of the perimeter

$p(i)$ perimeter value of the segmented i^{th}

n total of all segmented

$$\begin{cases} R < 0.6 \\ p(i) > p_T \end{cases} \Rightarrow Overlap \tag{9}$$

$$\begin{cases} R < 0.6 \\ p(i) < p_T \end{cases} \Rightarrow Occluded \tag{10}$$

where, R roundness value.

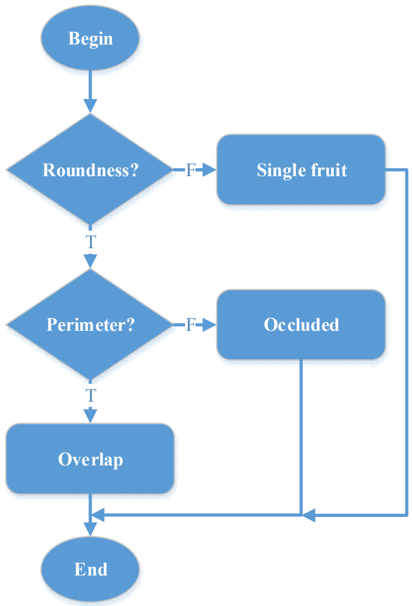


Fig. 5 The diagram of size estimation

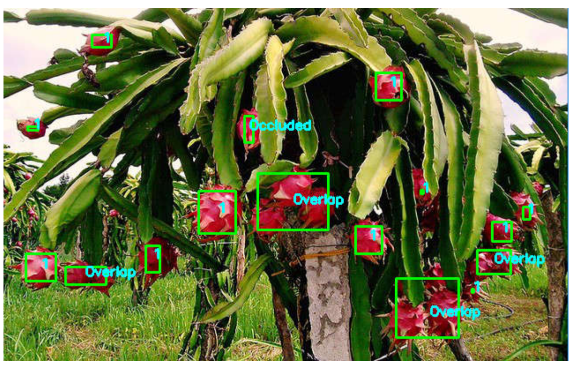


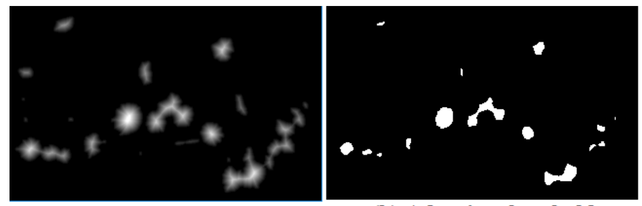
Fig. 6 The results of identify overlapping areas

E. Identification of oversegmentation

One of the big issues of Otsu algorithm is oversegmentation when it is used for image segmentation. Oversegmentation happens when a granule is segmented into two or more segments. These segments from the same granule are called oversegments in this paper. So, we need to separate overlapping regions using adaptive segmentation.

1) Distance transform

The distance transform [8] is an operator normally only applied to binary images. The result of the transform is a gray level image that looks similar to the input image, except that the gray level intensities of points inside the foreground region are changed to show the distance to the closest boundary from each point. That method is usually applied after the image segmentation process (Fig. 7). The purpose of this algorithm to separate some segmentation are overlapping to single objects. The disadvantage of this algorithm is that when we focus on separating large segmentation and small segmentation is disappearing. The distance transform is usually applied to some problem having the perimeter of regions are small difference. However, the problem of The project having the perimeter of regions is a large difference, because the distance from the camera to each dragon fruit is different. Therefore, the project required a method to solve the problems exist of this project.



(a) Distance transform **(b) Adaptive thresholds**

Fig. 7 The results of separate objects by distance transform

2) Adaptive segmentation

In order to alleviate oversegmentation, we develop a hybrid algorithm to reduce it. The propose of the new algorithm is called adaptive segmentation to reduce overlapping regions in image segmentation as shown Fig. 6. This algorithm base on the perimeter value of overlapping regions to make adaptive thresholds in the binary threshold. The process of identity oversegments is shown in Fig.8.

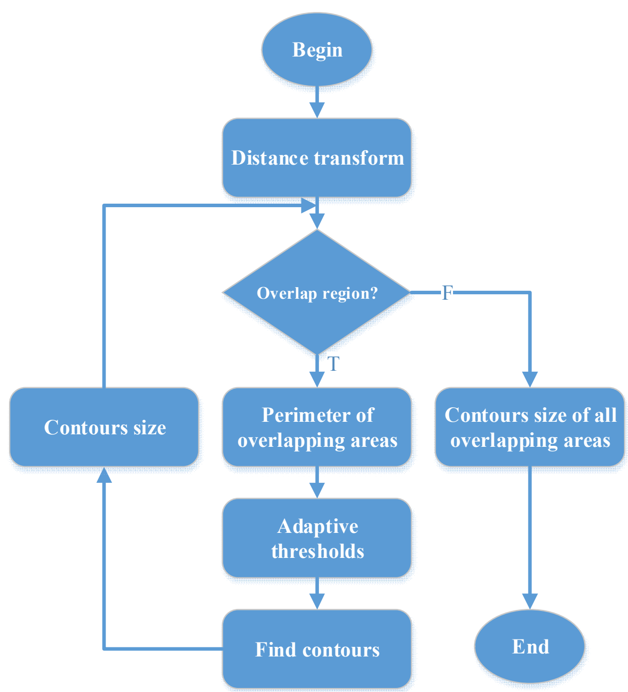


Fig. 8 The diagram of oversegmentation identification

This process is repeated many times based on the number of overlapping regions and perimeter of each region (Fig. 9) basis step is described as following:

Step 1: Use distance transform for overlapping regions.

Step 2: Determine overlap size to make an epoch for identifying oversegments process.

Step 3: Find adaptive thresholds by a perimeter of overlapping regions (the initial database of the adaptive thresholds is created from trial and error).

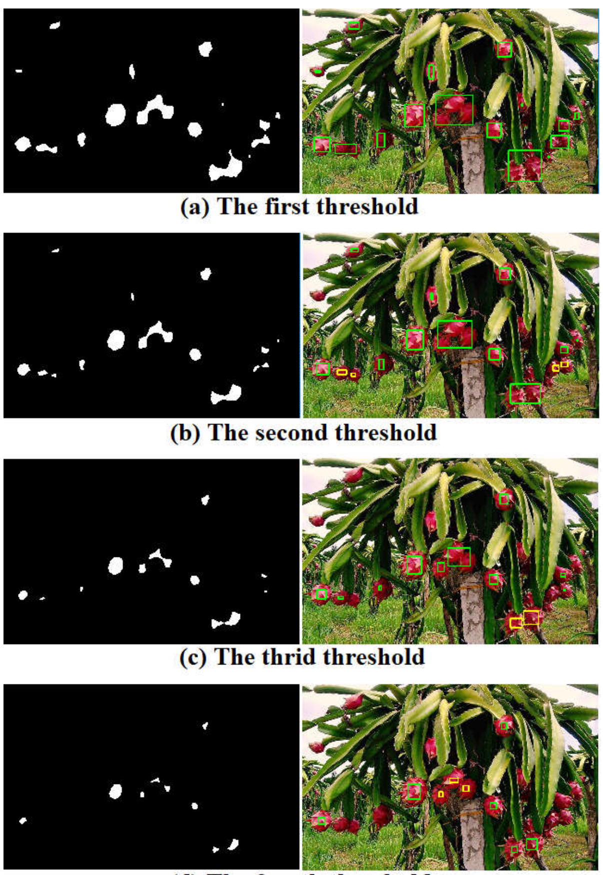
Step 4: Build contours for the new segments.

Step 5: Decide the number objects cover in one region by contours size.

Step 6: Consider next overlap region, turn to step 3; otherwise turn to step 7.

Step 7: Obtain number of fruits based on contours size of all overlapping regions.

After the identification process is over, the method is used to synthesize these regions to produce the final result.



(a) The first threshold

(b) The second threshold

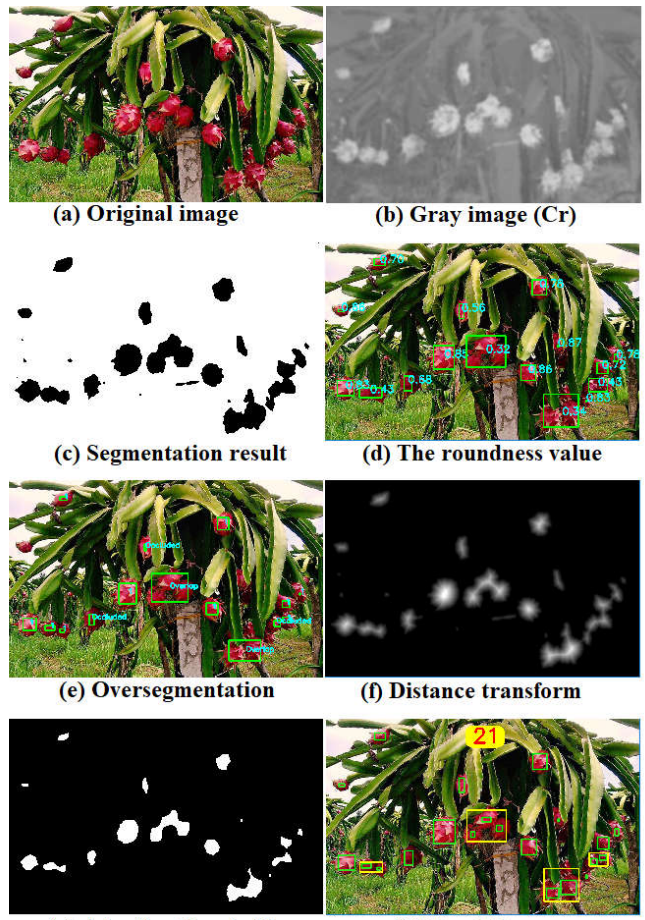
(c) The thrid threshold

(d) The fourth threshold

Fig. 9 The results of oversegmentation identification

III. EXPERIMENTAL RESULTS

In this part, we will be illustrated by some typical identification results for identifying, detecting and estimation of dragon fruit production in agriculture. Experimental results were made on the computer and dragon fruit samples collected from internet sources. The process of identifying and counting the exact number of dragon fruit on a tree is shown in Fig. 10 and Fig.11. Fig. 10 (h) is the result obtained from the synthesis of the results of the adaptive thresholds for each image segment Fig. 9. The results of the automated counting algorithm are 21 dragons fruit and manual counting are 22 dragons fruit.



(a) Original image

(b) Gray image (Cr)

(c) Segmentation result

(d) The roundness value

(e) Oversegmentation

(f) Distance transform

(g) Adaptive thresholds

(h) Result image

Fig. 10 The results of dragron fruit counting

Fig. 11 shows the results accurate count is 7 dragon fruit. Fig. 10 (g) and Fig. 11 (g) are imagery of adaptive thresholds. In this particular case, the system can not recognize the fruit that is both obscured and overlapped. The system can not recognize and locate the dragons fruit in case of very small area of dragon fruit can be seen on input image because of obscured and overlapped too much to each others.

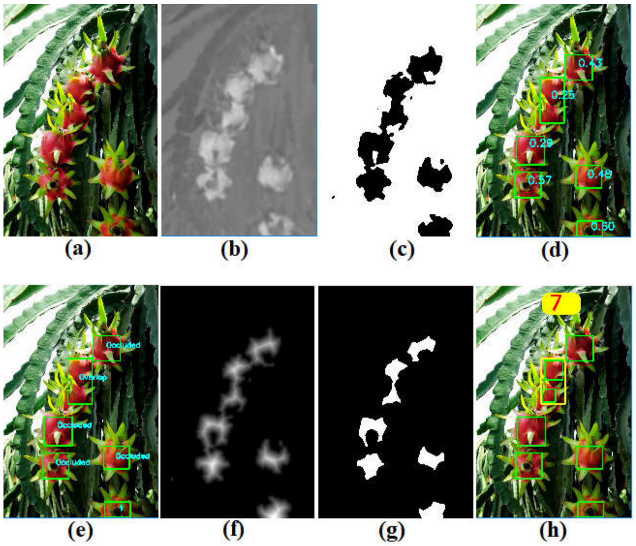


Fig. 11 The results of dragron fruit counting. (a) original image, (b) gray image, (c) segmentation result, (d) the roundness value, (e) oversegmentation, (f) distance transform, (g) adaptive thresholds and (h) result image.

IV. CONCLUSIONS

In this study, we present an image processing method for identifying, detecting and estimation of dragon fruit production in agriculture. The main algorithm in this project is to divide the single dragon fruit, the partly obscured fruit and the overlapping fruit to identify each other. This method works well in large regions and does not lose the information of small regions.

In the near future, we make a plan to build a real computer vision based on embedded system for getting the input image in the real environment of farm of dragon fruit. The target goal of our research is the design and making a robot vision for automatic harvesting and estimating the productivity of fruits.

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