

# **Tea Image Recognition and Research on Structure of Tea Picking End-Effector**

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How to cite this paper: Huang, B. and Zou, S.P. (2024) Tea Image Recognition and Research on Structure of Tea Picking End-Effector. *Journal of Electronics Cooling and Thermal Control*, **13**, 51-60. https://doi.org/10.4236/jectc.2024.133003

Received: August 25, 2024 Accepted: September 27, 2024 Published: September 30, 2024

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## Abstract

The automated picking technology of tea is an important part of the development of smart agriculture, which affects the development of the tea industry to a certain extent. Tea leaf recognition and robotic tea picking end-effector are the key technologies for automated tea picking. This paper proposes a set of algorithms for tea leaf differentiation and recognition based on the principle of colour difference. And on the basis of this algorithm, a tea picking endeffector is designed. The experiments show that the designed tea picking endeffector has good recognition ability and high tea picking speed.

## **Keywords**

Image Recognition of Tea Leaves, Tea Picking End-Effector, Tea Picking Structure Design

## **1. Introduction**

Tea is an important cash crop in China, widely planted throughout the country, and has become a pillar industry in some regions. In recent years, China's tea industry has been developing rapidly, as evidenced by the steady and slight increase in the area of tea plantations and the continued steady increase in tea production [1]. From the public data of China's National Bureau of Statistics, it can be seen that in 2023, China's tea plantation area reached 51,497,600 mu, an increase of 3.09% over the previous year; dry gross tea production reached 3.55 million tonnes, an increase of 5.97% over the previous year. With the current growth of the tea plantation area and the increase in tea production, "difficult to employ" "labour shortage" problem is becoming more and more serious [2] [3]. The use of tea picking robots for picking is an important way to make up for the shortage of

labour.

Research on tea-picking robots has been a hot topic in recent years, which mainly consists of a tea bud recognition system, a robotic arm and an end-effector [4] [5]. Compared with large tea picking machines, the compact design of tea picking robots is more suitable for complex terrain. The key to its research lies in the classification, recognition and localisation of tea targets. For example, in tea leaf recognition, Pan Z. et al. carried out a research on the identification and localisation of high quality tea picking points based on swing converter [6], Li H. et al. carried out a research on the detection model of tea buds in a real picking environment based on the improved YOLOv5 [7], and Fenyun Z. et al. carried out a research on the segmentation and detection of tea buds and the localisation of picking points [8]. The research on end-effector, as a key equipment for tea picking, has also received much attention. Yu Shilong designed the overall layout and programme of the tea picking machine according to the cultivation, management and related agronomic requirements of tea plantations in hilly and mountainous areas [9]. Shen Huiping et al. carried out research on hybrid tea picking robot mechanism to ensure accurate picking of tea picking robots [10]. Chen Jianneng et al. for the famous tea in the process of mechanised picking in the side buds cannot pick the problem, according to the top buds, side buds and tea stems of the relevant parameters and combined with the environment of the tea plantation designed an end-effector. This end-effector uses the bending deformation of the teeth of the split cutter to pick the side buds [11]. Zhang Zhihao et al. proposed improvement measures for the end-effector of a famous tea picking robot on the basis of summarising the problems of the end-effector of a famous tea picking robot [12].

With the continuous deepening of the research on tea bud recognition and the continuous improvement of the end-effector of tea picking robots, the structural design of the end-effector of tea picking based on image recognition technology has become a key technology to improve the tea picking robots. However, due to the limitation of hand tea varieties, the relevant research for Guizhou tea recognition has not been reported. For this reason, this paper carries out tea recognition research with tea in Guizhou province as the research object, proposes a set of tea image recognition algorithms, and designs a tea-picking end-effector on this basis.

## 2. Sources of Tea Samples and Introduction of Tea Plantation Bases

This study takes Guizhou tea as the research object. Therefore, to realise the design and development of the end-effector for tea picking, we need to understand the tea planting and picking situation in Guizhou Province. For this reason, we conduct a comprehensive investigation of the terrain, planting environment, and tea picking situation of tea planting bases in Guizhou Province, as shown in **Figure 1**. The famous tea base in Guizhou, Jiuan Township Ancient Tea Garden, is known as an important cultural heritage of "Ancient Tea Tree and Tea Culture System". It has preserved more than 54,000 ancient tea trees, with an average age of about 400 - 800 years, among which there are 19 tea trees that are more than 1000 years old. In addition, the area of artificially planted tea in Guizhou reaches more than 20,000 mu, with an annual production of about 300 tonnes of tea. The terrain of the ancient tea plantation is mainly mountainous, the overall area of tea plantation is small, and more inclined terrain, not conducive to the operation of large-scale machinery, which is also one of the reasons that block the popularity of mechanised tea picking in our province. Tea planting in the tea plantation row spacing of about 70 cm, tea tree height of about 80 - 110 cm. tea picking time for about 10 days before and after the Qingming Festival, but also summer and autumn tea picking. The tea leaves are also divided into buds, one leaf and one bud, two leaves and one bud, and other picking methods.



Figure 1. Tea plantation base.

## 3. Research on the Identification of Young Leaves of Fresh Tea Leaves Based on RGB Mode

We start by using the method of colour difference between young leaves and old leaves for identification. The most obvious difference between young and old leaves is their colour. Young leaves are yellowish green or light green when they are freshly grown, while old leaves are darker and have a darker green colour. It is easy to differentiate between young and old leaves by human observation, but to use a computer to differentiate between young and old leaves, it is necessary to extract the colours of young and old leaves to find the pigmentation difference, and there are corresponding procedures. **Figure 2** shows the team members using matlab for tea leaf image processing in the studio.

After investigation, we found that the yield of tea leaves of one bud and one leaf is relatively high and better in terms of quality, which is the main body of tea picking. We picked some young and old leaves of one bud and one leaf in the ancient tea base in Jiuan Township, placed the picked old leaves and young leaves of one bud and one leaf on A4 paper, and set the image background to white to remove the background noise interference. As the light has a greater impact on the captured image, so the image acquisition was carried out in an indoor environment without direct sunlight, using an industrial camera model HF867 facing the paper to shoot, the camera distance from the leaf 20 cm, the number of images is 10, the size of  $640 \times 480$  pixels, as shown in **Figure 3**.

In order to find out the relationship that exists between the components, the data were processed and line graphs of R, G, and B values of old and young leaves were produced, as shown in **Figure 4** and **Figure 5**.



Figure 2. Tea image processing site map.



Figure 3. Sample image of tea identification study.







Figure 5. R, G and B folding diagrams of young leaves.

In Figure 5, the R and G components of young leaves are more obvious because of their brighter colour, and the overall analysis of the B component is weaker. Comparing Figure 5 and Figure 6, it is easy to find that the relationship between the R and G components of the old leaf and the R and G components of the young leaf has a big difference. The G component is almost always larger than the R component at each pixel point of the old leaf, and the G component is almost as large as the R component at each pixel point of the young leaf. Therefore, there exists a segmentation threshold M between the R/G of old leaves and the R/G of young leaves, and there is also a difference in the B component, so the recognition algorithm for young leaves is proposed, *i.e.*, the pixels with R/G>M, and B<N are judged as young leaves, and the rest of the pixels are judged as the background, and the segmentation thresholds M and N are affected by the light intensity, the type of tea, and the shooting angle, so that the recognition effect of the young leaves depends on the segmentation thresholds M and N. There are many value segmentation methods. and N. There are many value segmentation methods. Such as Otsu method, histogram bimodal method, and so on. Figure 6 shows the R/G line graph of old and young leaves.



Figure 6. R/G fold plot of old and young leaves.

From the above figure, it can be clearly seen that the R/G values of the two types of tea have a very obvious difference, the R/G of the pixel points of the old leaves

is smaller between 0.6 and 0.91, while the R/G of the young leaves is larger between 0.91 and 1.3. So for the experimental material used in this experiment, the value of segmentation threshold M is 0.91, N is 0.51, and the R/G crossover rate is 3% (crossover rate = number of out-of-bounds pixel points/total number of pixel points). The method achieves 100% recognition rate for young leaves. Since the ratio is extracted based on the colour features of the leaves, this method of using the difference between the R/G of old and young leaves to identify the old and young leaves of tea is called the ratio method. The advantage of this method is that it does not require high pixel of the picture, high recognition rate and small limitation, the disadvantage is that it requires light and shooting angle, and the segmentation thresholds M and N will be changed when the light is changed, but the change is not too big.

For the sample image, the segmentation threshold M of 0.91 and N of 0.5 were effective in removing old leaves and background. Pixel points with R/G values above 0.91 and B/255 less than 0.51 are retained when processed using Matlab software. In this way, the pixel points of the young leaves are basically retained, and the pixel points of the old leaves and the background are basically turned into pure white, and the processing effect is shown in **Figure 7**. Through the experiment, it can be found that the method of extracting the young leaves by using the difference between the R/G of the old and young leaves is feasible.



Figure 7. Extraction of young leaves by proportional method.

As can be seen in the above figure, although most of the old leaves can be removed using the proportional method, the edge portion and the middle portion of the old leaves are still present. The RGB values of the pixel points in the edge part are similar to those of the young leaves due to the light and the colour of the leaf edges, so they cannot be removed simply by the proportional method. Next the preliminary processed image needs to be processed with noise reduction and median filtering to remove the edges of the old leaves and some noise in the image.

The vast majority of the pixel points of the young leaves are gathered together in a clearly larger connectivity domain area, and the noise is gathered in a smaller connectivity domain area. Therefore, the noise can be effectively removed by the method of denoising the connectivity domain area. It can be understood as stipulating that the area of a connected domain is N, and the area of the connected domain of the pixels left behind after the preprocessing is S. In the denoising process, the R, G, B values of all the pixels in the region will be changed to 255 when S < N. 11 \* 11 median filtering of the image is carried out by Matlab, and the process can eliminate the pixels remaining at the edges of the old leaves, and the processing effect is shown in **Figure 8**.



Figure 8. Effect of noise reduction and filtering processing.

In order to verify the reliability of the method, we use the proportion method described above for initial extraction, and then the processed images are processed for noise reduction and filtering, and several tea plants are extracted for young leaves, and it is found that the recognition effect is all relatively good, but by the influence of light and shooting distance and angle, etc., the segmentation threshold and the parameters such as noise reduction and filtering will produce some changes.

#### 4. Development of Tea Picking End-Effector

The tea picking end-effector works differently from existing non-selective tea pickers. It needs to first identify the young tea that can be picked, then move the end-picking device to pick the tea leaves, and then recycle the picked tea leaves through the collector. Only one piece of tea is picked at a time, and another piece of tea is picked after the collection is complete.

Existing tea plucking machines use a spiral cutting type or reciprocating shear type for plucking tea. The tea obtained by this picking method will contain old leaves and branches, which will lead to lower quality of tea. To address this drawback, we have designed an end-picker. This end-effector picks only one tea leaf at a time, so it can target young leaves and improve the quality of the tea.

The tea picking end-effector we designed mainly consists of cylinder, frame, light bar, moving tool holder and fixed tool holder as shown in **Figure 9**. The cylinder is mounted on the frame as a driving device. The two light bars installed in the frame are used as the sliding rails of the mobile knife holder. The fixed tool holder is mounted inside the frame. The cylinder arm is attached to the mobile tool holder. Cutting knives are mounted on the mobile knife holder and the fixed knife holder. The lower part of the frame is provided with a picking hole which passes through the tea leaves. A corresponding collection hole is provided in the lid, which is connected to a pipe of a negative pressure device. In addition, an industrial camera is mounted on the outside of the rack and is used for collecting

images of the tea leaves.

When working, the camera first acquires images of tea leaves, which are processed to identify the young leaves that can be picked. Then move the mechanical arm to move the end-effector to the top of the young leaves. At this time, the cylinder is in a contracted state, and the young leaves are set in the end picker through the picking hole. After that, the cylinder works and pushes the mobile knife holder along the light bar through the cylinder arm, and the knives on the mobile knife holder and the fixed knife holder come together to form a shear to cut off the young leaves. After that, the negative pressure device is activated and the tea leaves are sucked up and collected through the pipe. Finally, the cylinder wall is retracted to complete a complete picking action.

# 5. Commissioning and Experimentation of Tea Picking End-Effector

Through continuous structural optimisation, we have completed the tea picking end-effector prototype fabrication and carried out prototype debugging and experiments, as shown in **Figure 10**. The experimental results show that the tea picking end-effector based on our design has a high recognition rate of tea, and the speed is 5 - 10 times higher than that of manual, which effectively improves the efficiency of tea picking.



Figure 9. Effect of noise reduction and filtering processing.



Figure 10. Prototype and experimental site of end-picking actuator.

## 6. Conclusion

In this paper, a set of tea leaf recognition algorithms is proposed based on the RGB mode for the colour difference analysis of young and old leaves, and on this basis, good results are achieved. And based on the proposed tea leaf

recognition technology, the corresponding tea picking end-effector is developed. The experiment shows that the tea picking end-effector has the characteristics of high tea leaf recognition rate and fast speed, which can effectively improve the efficiency of tea picking, and to a certain extent, it advances the progress of automated tea picking technology research.

#### Acknowledgements

This study was supported by the Science and Technology Plan Project of Guizhou Province (Grant No. QKHJC [2019]1152) and High-level Talents Research Initiation Fund of Guizhou Institute of Technology (Grant No. XJGC20190927). Initiation Fund of Guizhou Institute of Technology (Grant No. XJGC20190927).

#### **Conflicts of Interest**

The authors declare no conflicts of interest regarding the publication of this paper.

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