Research on Stalk Crops Internodes and Buds Identification based on Computer Vision

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Abstract. The equipment of stalk crops seed manufacture at present has defects in precision and intelligentize, which results in bad quality and low survival rate of the seeds. In this study, computer vision technology is applied to obtain the internodes and buds information of stalk crops, identifying and matching the objective characteristics. Here we summarized the system of computer vision that used to identify the internodes and buds of stalk crops, including three modules: camera calibration, high-speed vision technology and digital image processing. Digital image processing methods which used for recognizing the characteristics of stalk crops are analyzed and generalized. The internodes and buds identification method of stalk crops was put forward in this study. Based on the current research condition, finally, this paper discussed issues and study prospects in the field of stalk crops characteristics identification.

1. Introduction
High-quality seeds are often desired in the field of plant stalk crops. However, due to the limitation of seed manufacture equipment, the seeds we obtain always perform poorly both in quality and survival rate. The equipment present would destroy internodes and buds of the seed always, which account for the machine could not identify the internodes and buds of stalk crops.

Internodes and buds identification of stalk crops is based on computer vision, which can make significant advances in information collection, intelligent decision and operation accuracy. Computer vision is defined as using the image sensor and computer to replace the human eyes and brain, enforcing the mission likes classification, segmentation, recognition, tracking, identification, and decision-making. Computer vision can improve agricultural equipment level and facilitate the fusion of agricultural equipment industry [1]. Furthermore, the study can also provide an integrated proposal which would be beneficial to informationize the seed manufacture equipment of stalk crops.

This study focuses on the system of computer vision that used to identify the internodes and buds of stalk crops, including three modules: the camera calibration, high-speed vision technology and digital image processing. It also summarized the research achievement at present, and how to identify the internodes and buds of stalk crops was proposed. Finally, this study discussed prospects of practical application in the field of characteristics identification.

2. Image Acquisition

2.1. Camera Calibration
Computer vision system obtains the image information by CCD camera, and calculates three dimensional geometric parameters at this moment [2]. Camera calibration is the first step to gains 3D
parameters and reconstruct 3D scene. The accuracy of calibration can influence the result of structure. Camera calibration is a process which based on using a set of known spatial location and corresponding image points to work out internal and external parameters\cite{3}. The physical structure for capturing stalk crops’ internodes and buds image processing is shown in Fig. 1.

![Physical structure for capturing stalk crops’ internodes and buds image processing](image)

Fig. 1 The physical structure for capturing stalk crops’ internodes and buds image processing

There are three kinds of camera calibration methods: the traditional calibration method, self-calibration and the calibration based on initiative vision. The traditional calibration method has three ways: linear calibration, perspective transformation matrix and perspective transformation matrix \cite{4}. Linear calibration method can deduce projection matrix from the relationship of two coordinates. It is only applied in an ideal linear condition because the robustness and accuracy of this method is not high enough, which derive from the influence of distortion factor on the accuracy is neglected \cite{5}. Martins\cite{6} put forward a more reasonable method that named double plane calibration. It is based on the model of camera imaging, but the system sensitivity is poor. Zhang Zhengyou used the plane template instead of solid calibration block to improve the robustness and accuracy \cite{7}. But it also ignored considering the influence of camera lens distortion factors when calibrated the fish-eye lens \cite{8}. Liu Yan has come up with a method of modified two-stage calibration and optimized the drawback of the fish-eye lens, which is based on the Zhang Zhengyou calibration. But still need to further improve the accuracy of the lens.

Self-calibration method is based on the Krupp equation to establish absolute quadratic curve for the camera, which possesses the properties of Euclidean invariant. The method requires less strict experimental environment. But it has disadvantage than other methods in robustness and accuracy \cite{9}.

The camera calibration based on initiative vision has advantage in simple algorithm, speediness and high robustness. But it needs to control the movement of the camera, and the operation is quit complicated. Furthermore, the hardware is expensive.

2.2. High-speed Vision

With the rapid development of software and hardware technology, the quality of large size CCD and CMOS sensor have significantly improved. It is possible to obtain the high frequency and mass density image data of the stalk crops in high-speed motion. High-speed vision technology consists of image acquisition and data processing while they generally work concurrently. As the sampling frequency up to 1 KHz, the image resolution of high-speed moving object has greatly improved. High-speed vision generally applied in quick response system \cite{10}.

Guo Yin \cite{11} used binocular stereo vision to measure the dynamic pose of high-speed moving objects. But the vibration of high-speed target affects accuracy of the system and imaging quality. Lei Xiujun \cite{12} adopted monocular vision technology to capture target digital images in long distance and high-speed state, and taken use of chaotic particle swarm optimization and local search optimization to improve the stability and robustness of digital image at the same time. However, due to the limitation of monocular vision imaging, the inaccuracy of the system they implemented was not satisfying.

What’s more, a high-speed camera with sampling frequency higher than 30fps can generate a
huge amount of data processing tasks\textsuperscript{[13]}. So, how to deal with the huge amount of data in real time and meet the real-time performance of the system can be major bottleneck of the development of high visual technology. Yu Xiaoyu\textsuperscript{[14]} led parallel computation into the process of high speed vision measurement. He solves the bottleneck of real-time feature extraction, recognition and high speed data streams matching. Nevertheless, this program requires a large number of sites to track information, and the present performance of DSP can’t meet the real-time requirement of the system. High-performance DSP with multi-cores can identify internodes and buds of stalk crops. Meanwhile, this scheme can solve problems above with co-operation effectively.

3. Feature recognition for Stalks Crop's internodes and buds

Feature recognition for the object has been extensive researched in the past 30 years by domestic and foreign scholars. Z. Wang from the United States used Hough transform to detect the straight line sugarcane seeding. It applied computer vision system to separate the sugarcane test-tube plantlets\textsuperscript{[15]}. Moshashai k\textsuperscript{[16]} from Iran adopted the threshold segmentation method of computer vision technology to identify the internodes of sugarcane in static state. But he neglected to identify the sugarcane internodes that in motion.

Zhao Jinhui\textsuperscript{[17]} carried out a method of image segmentation to detect the sugarcane diseases. It based on the color and shape characteristics of object. In order to improve the adaptability of edge detection algorithm, Jin Gang\textsuperscript{[18]} put forward an adaptive Canny edge detection algorithm. It is based on improved genetic algorithm to obtain the threshold automatically, and it is hard for the traditional algorithm to solve the bottleneck. However, it fails to explain effectively the doubt that how to choose the smoothing scale of the image in Canny algorithm. Moreover, it has no experiment to verify the threshold that based on the histogram trough is more effective than Otsu method. Especially, it ignored demonstration which method is more excellent to eliminate the background noise and segment the object region.

3.1. Digital Image Processing

The physical type of the internodes and buds of stalk crops is complex and diverse. It results in impurity noise interfere with the accuracy of identify and extract the feature of stalk crops. Fig. 2 shows the flow chart of image processing. It is a flow of how to obtain the distinction of target effectively.

![Fig. 2 The flow chart of image processing](image-url)

The image processing of the internodes and buds of stalk crops including two modules: image preprocessing and label internodes and buds. The flow of image preprocessing is: convert the acquired image unit to S component, filter denoising, object extraction, image enhancement. The target feature image labeling flow is: obtain the binary image of internodes and buds, DCT analysis and calculation, FCM algorithm clustering and label internodes and buds.
Furthermore, this study applied HSV color space transformation to process stalk crops RGB image, and the image is acquired by image acquisition. Finally, the system receives the S component of object. Due to the edge and noise of stalk crops are discontinuous in the S component image. When the frequency domain is high frequency components, it is difficult to obtain effective edge profile. If the differential operation is performed directly, it will be difficult to obtain the profile. Median filter is a nonlinear processing method that can suppress the random noise effectively. The fuzzy degree of the image detail is much lower than the linear smoothing filter \[19\]. In other words, median filter can remove the noise while it could preserve image details \[20\]. That’s why this study chooses it to filter the S component image.

Canny algorithm can detect the vertical, horizontal and diagonal direction of image edge with four masks. The algorithm can achieve a favorable balance between noise suppression and edge detection. It ultimately generates a luminance gradient map of each point in the original image. It can deal with the S component image of the target area edge that may point to different directions. Therefore, Canny edge detection algorithm is used to extract the upper and lower edge profile of the S component image of the internodes and buds of stalk crops. Due to the twice differentiable of Gaussian function \(\delta(x)\), Canny algorithm uses Gaussian filter to smooth image of the target. \(\psi^a(x)\) and \(\psi^b(x)\), respectively, one order and two order differential function of \(\delta(x)\), which is shown in the formula (3-1),

\[
\psi^a(x) = \frac{d\delta(x)}{dx}, \quad \psi^b(x) = \frac{d^2\delta(x)}{dx^2};
\]

Canny found that the first order reciprocal of Gaussian function can approximate the Canny criterion perfectly. Gaussian function \(G(x,y)\) is shown in the formula (3-2).

\[
G(x, y) = \left(\frac{1}{2\pi\sigma^2}\right) \exp[-(x^2 + y^2) / 2\sigma^2]
\]

This study uses Laplace image sharpening to enhance image. It can make the feature of stalk crops more clearly. The gray contrast of the target area was enhanced. What’s more, the difference between stalk crops and background are further increased.

### 3.2. Label the internodes and buds

Otsu threshold segmentation method is applied to reprocess the image, which is processed by Laplace sharpening enhancement. The optimal threshold can be determined by analyzing the one-dimensional histogram of the image. The system obtains the binary image in the target area finally.

The feature of the internodes and buds of stalk crops is characterized by the parameters that calculated by two dimensional DCT. To obtain two-dimensional DCT transform matrix, the one-dimensional DCT transform and DCT inverse transform should be proceed firstly. They are shown in the formula (3-3), (3-4),

\[
c(s) = a(s) \sum_{x=0}^{n-1} f(x) \cos \left(\frac{2\pi + 1}s x\right) \frac{s\pi}{2n}, s = 0, 1, \ldots, n-1 \quad (3-3)
\]

\[
f(x) = \sum_{x=0}^{n-1} a(s)c(s) \cos \left(\frac{2\pi - 1}s x\right) \frac{s\pi}{2n}, x = 0, 1, \ldots, n-1 \quad (3-4)
\]

The orthogonalization coefficient \(a(s)\) is:

\[
a(s) = \begin{cases} 
\sqrt{1/n} & s = 0 \\
\sqrt{2/n} & s = 1, 2, \ldots, n-1 
\end{cases}
\]
Two-dimensional transform matrix is shown in the formula (3-5),
\[
c(s,t) = a(s)a(t) \sum_{x=0}^{n-1} \sum_{y=0}^{n-1} f(x,y) \cos \left( \frac{(2x+1)s\pi}{2n} \right) \cos \left( \frac{(2y+1)t\pi}{2n} \right)
\]
(3-5)

Among it, \(s, t = 1, 2 \ldots n-1\).

The FCM algorithm is used to cluster the target feature. The final results of clustering are classified into the feature of buds and non-feature in the target area. And system marks the internodes and buds in the image.

4. Conclusion
The research on internodes and buds of stalk crops identification belongs to intelligent information technology of exquisite agriculture. It is significant to improve comprehensively the performance of visual operation in the application occasions and conditions. Currently, the sensor information collection efficiency of high-speed moving target is not high enough. It is difficult to percept and discriminate the seed buds of stalk crops. The seed buds identification accuracy also is not high. The following several points can be studied continually in the next stage.

A. Accurately and efficiently label target feature

At present, the image acquisition hardware limits the performance of information collection. So, the sampling frequency and the processing efficiency aren’t high. In practical application, the sensor should react and gain the image information of the target quickly. The processing system can effectively distinguish the internodes and buds, and then mark the object accurately. It is favorable to use high speed vision system to optimize the algorithm of the high speed image acquisition. It can improve the dynamic response performance of computer vision to high speed moving objects.

B. The real-time detection system of linear scanning multi-vision of the target

In the past, most of the image acquisition modules of stalk crops’ internodes and buds were single image collectors. The overall imaging range is limited and the image acquisition efficiency isn’t high. The high-definition image is obtained by the real-time detection system of linear scanning multi-vision. The acquisition card transfers data directly to computer memory. Computer terminal is applied to extract and label the internodes and buds in real time. The processed images were jointed and analyzed statistically. The system can expand the range view of image acquisition terminal. It can improve efficiency of the whole system. The fault tolerance of the system has been greatly enhanced. In the future, the study could enhance the fault-tolerance of linear scan camera imaging system. Moreover, uncalibrated multi-camera system and image real time processing system also require further research.

C. Hardware and algorithm

Image processing terminal should be equipped with real-time and efficient image processing hardware to meet the requirements of the algorithms. A single quad-core CPU and the Canny algorithm are widely used in the terminal. But its image processing speed is still not satisfactory. Canny algorithm requires high configuration of hardware to meet its wide-area adaptability. The parameters can be adjusted to meet different characteristic of the edge in specific working conditions. Especially, the efficiency of the system is greatly affected in the use of Gauss filter. The processing terminal can be equipped with multiple core processors to solve above problem. Meanwhile, the framework of Canny algorithm can be optimized to adapt for stalks crop.

D. Man-machine collaboration system

When computer vision system processes the object with complex background noise or external disturbance, the reliability of system is significantly decreased. The physical characteristics of stalk crops are complicated in different regions. Previous man-machine coordination system mainly focused on design of the system configuration. Stalk crops man-machine collaboration is less researched. Especially, the development of man-machine co-recognition system based on computer vision for internodes and buds of stalk crops has a certain application prospect.
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