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Direction Identification System of Garlic Clove Based on Machine Vision

Gao Chi*, Gao Hui
Laiwu Vocational and Technical College
Phoenix northbound High-tech Zone of City Laiwu, Province Shandong, China, +86-0634-6427409
*Corresponding author, e-mail: wwwgc119@163.com, gaohui_l@163.com

Abstract

In order to fulfill the requirements of seeding direction of garlic cloves, the paper proposed a research method of garlic clove direction identification based on machine vision, it expounded the theory of garlic clove direction identification, stated the arithmetic of it, designed the direction identification device of it, then developed the control system of garlic clove direction identification based on machine vision, at last tested the garlic clove direction identification, and the result of the experiment certificated that the rate of garlic clove direction identification could reach to more than 97%, and it demonstrated that the research is of high feasibility and technological values.

Keywords*: garlic clove; direction identification; machine vision*

1. Introduction

In order to guarantee the quality of garlic products, the bud of garlic clove often needs to be planted upwards. But as a result of the irregular shape of garlic clove, it only can be planted by manual work for quite some time. The human-planted mode is of high labor intensive, it does not only waste time and energy, but also has low productivity and high cost. So mechanization of garlic planting is urgently needed. Direction identification of garlic clove is one problem of impeding garlic planting mechanization. There're many researches about shape recognition of agricultural crops, for example, Satoshi YamamoLo, et al [1], [2], whose research on strawberries harvest by binocular color camera, it could recognize strawberries' characteristic information of position, direction and shape in the natural state; Maja Musse and other people whose research on cherry and tomato harvest, they used binocular stereo imaging technology to detect cherry and tomato's position, the accurate rate reached to 70%; Ruiz L A and other people's research on the recognition of oranges in condition of outdoor natural light, the recognition rate is 75%; Domestic scholar Rui-he Zhang and others orientated red tomatoes by vision technology; Wen-jie Zhao and others used binocular vision to identify ripe tomatoes; Yi Xu and others' research on iceberg lettuce could recognize the iceberg lettuce and its' position. And there're a few researches studied on garlic clove identification specially, for example analyzing garlic clove shape by image processing [3], some proposed pattern recognition [4], [5], but all the researches are still in experimental stage, they are lack of data support, and they were designed and researched by large-scale software in the laboratory, the results are far away from the requirements of practical application. Although the judgment and adjustment research of garlic clove direction identification is still in exploration stage, but it has built correlation technique foundation.

The environment of garlic planting is complicated, the garlic cloves are usually been put in the garlic-box, and planted in the field artificially. In the natural conditions, as the spatial position and direction of garlic cloves are random uncertain in the garlic-box, it is quite difficult to distinguish each garlic clove, and recognize their spatial position and direction. So the information provided to manipulator to complete planting is not so clear. According to years of experimental research, the paper proposed a method of garlic clove direction identification based on machine vision, developed an identification system taking singlechip as control unit, and identified garlic clove by technical identification device.

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2. The Proposed Algorithm

As figure 1 shows, the sizes of garlic cloves are different, so their shapes are irregular, so it is rather difficult to identify the garlic cloves, especially their direction. Common methods and theories can hardly realize high accuracy identification; they can't satisfy the requirement of garlic planting. But observing and analyzing the bud and root characteristic of garlic clove, the bud of each garlic clove is long and thin, the width is narrow (the width of garlic clove is the distance between the back and the sector beginning of garlic clove; the length of garlic clove is the vertical distance between the root and the bud of garlic clove), and changes obviously; the root is thick and wide, and changes slowly. On the basis of the feature, during the identification, when we use visual sensor to collect information of garlic cloves, we can only collect part of the root and bud information to judge the part is the root or bud of garlic clove, the identification method can reduce the amount of information we need to deal with during the identification process. Therefore the paper proposed a identification method to recognize the direction of garlic cloves by limit their positions and using visual sensor to collect part of their information.

Figure 1. The feature map of garlic cloves' shape

The principle of the method is as follows: first, designed specified recognizer to limit garlic cloves' position, as picture 2 shows, the recognizer is a black rectangle groove, the length is less than 3cm, and width is less than 2.5cm, it can contain a garlic clove as big as shown in picture 2, it enter into the recognizer only on two ways, root below or bud below. Small garlic clove may enter into the recognizer obliquely but cannot enter into the recognizer horizontally. In the meantime, in order to position the garlic clove, the two sides of the recognizer are set cambered, and vertically symmetrical, it can rotate 180° driven by position motor. At the same time, it must keep a certain inclinations, usually less than 30° when it is working. By this means it can ensure the garlic clove move down freely under the action of gravity, and don't need to rotate by itself, it can keep the clove slipping down the garlic delivery hose to the recognizer freely. And then the position of garlic clove is limited in the recognizer, root below or bud below.

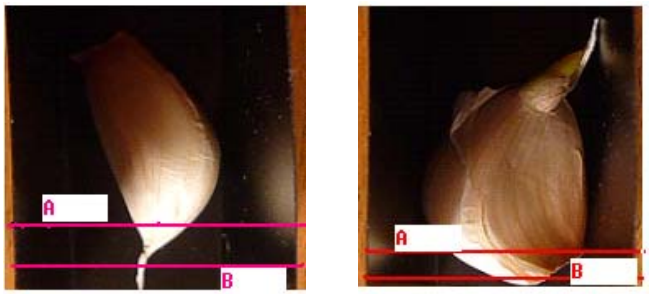


Figure 2. The schematic of information collection

We can only collect the information of root or bud below the recognizer, but not all the information of garlic clove, just as figure 2 shows, the position is near line A and line B, for the

information collected, the part we judge and process is only the root or bud of garlic clove. And the color of recognizer and background is dark black, so when we collect information, the garlic clove can be distinguished clearly. As figure 2 shows, we collect information of line A and line B of the root or bud according to their different gray values, then calculate the actual width of garlic clove in line A and line B based on the different gray of line A and line B, then on the basis of the change of actual width, calculate the edge flexion and identify whether it is root or bud. In figure 2, line A means the top line, and line B means the bottom line. Here we just take an example to illustrate the recognize principle, we need to collect more lines in practical.

3. Research Method

3.1. Image Processing

As the the information collecting using specific identification device, and the vision sensor and identification device are fixed, so we take identification device as a reference to realize the calibration. As the aim of recognizing clove is to plant garlic, so the main work is doing out of doors, and the intensity of light changes a lot during the day, so the images need to be optimized during planting and use light adaptive method [6] to resolve the influence of light change on vision detection. Based on the influence of environment light intensity on vision sensor's white balance and exposure time directly, the light adaptive design sets and controls the related registers by software. It can directly read the intensity data of vision sensor without detecting other photo sensors, and the reliable intensity data is a basis of light adaptive processing. The adaptive processing uses automatic mode, adjusts and processes the set of vision sensor partly, and divides the collected intensity data into two control sections, for instance, 8 bit of intensity data is been divided into two sections, a section is lower than 96Hz, the other one is higher than 96Hz. The intensity processing of vision sensor is proceeding separately after booting and before working, on this way, it could reduce the system burden. In the automatic adaptive section, it only needs to set the related registers such as intensity, white balance, exposure time and so on to automatic mode, and get the intensity adaptive data by CMOS chip automatically. On account of the change's nonlinearity, model uncertainty and control objective requirement of environment intensity, we extract the control rules through qualitative analysis, combine experience of light adaptive processing in real environment, tune the parameters, and establish expert control knowledge base at last [7], [8]. We divide the intensity deviation into 7 grades during selecting control variable, E={En1, En2, ···, En7), it means we set positive and negative difference into 7 grades. The difference of exposure time is divided into 5 grades, T={T1, T2, ···, T5}, white balance adjustment is divided into 3 grades, W={W1, W2, W3}. Condition on the difference between outdoor light intensity and target value, we decide the adjustment settings of intensity output, white balance and exposure time registers. Figures before and after adaptive processing are shown in figure 3.

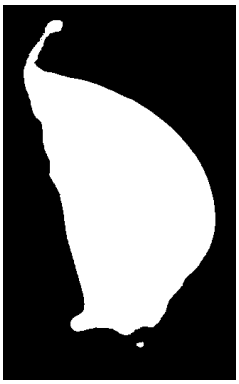
a. Figure before adaptive processing

b. Figure after adaptive processing

Figure 3. Figures before and after adaptive processing

The information of garlic clove needs to be processed by binarization method after light adaptive processing. The implementation of garlic clove positioning requires the position of root or bud detecting from the figures. Pictures we took always have some noises; these noises will affect the accuracy of stereo matching. As the origin of the noises are all spread around the edge of clove, so we use median filter to eliminate them. The median filter can not only eliminate discreet noise, but also overcome the picture blurring; it is a common non-linear filter. The main idea is taking a gray scale mid-value in a neighborhood of current point of the picture instead of the gray scale value of the point, shifting on the picture successively with a sliding window which contains odd pixels, rearranging pixels of the window in every position in order of size, and taking the mid-value of gray scale as the output value of window's center pixel. Then processing the picture by median filter, and implementing image binarization by edge zero crossing binarization arithmetic. At first, we only process the edge pixels, detect the edge and divide local pixels of the two sides into background and target [9]. When the local pixels are all target or background, we'll confirm it as undetermined region, then connect with region mark, finally estimate which class does it belong to on the basis of the attributes of the pixels around the connected region after marking, and complete binarization correctly. Picture that before or after edge extracting is shown in Figure 4.

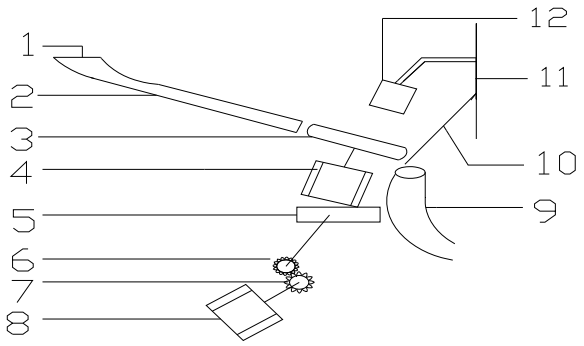
a. Figure before edge extraction



b. Figure after edge extraction

Figure 4. Figures before and after edge extraction

3.2. Identification Devices



1. Entry of garlic clove 2. Delivery hose of garlic clove 3. Recognizer 4. Position motor 5. Position supports 6. 7. Change gears 8. Eject motor of garlic clove 9. Exit of garlic clove 10. Recognizing baffles 11. Support 12. Camera

Figure 5. Diagram of Identification device

As figure 5 shows, the identification device is composed of identification part and position part, identification part consists of entry of garlic clove, delivery hose of garlic clove,

recognizer, recognizing baffle and camera. The delivery hose of garlic clove is smooth and keeping a certain inclination less than 30°. The camera is fixed on the same support with recognizing baffle on the top of recognizer. Garlic clove could fall down to the recognizer through entry and delivery hose freely, and be stopped by recognizing baffle. At that moment, the garlic clove is root-on or bud-on, then the camera collects part information of root or bud below recognizer only, and finally the controller estimates whether it is the root or bud on the basis of the information collected from line A or line B of the root or bud [10]. The position adjuster consists of position motor, eject motor of garlic clove, position support, change gears and exit of garlic clove. Both sides of the recognizer are arc-shaped, vertical and horizontal symmetry, it can rotate 180° driven by position motor. As the position adjuster is light, the position motor selects low power and low speed DC motor, and the size is small, so it is fixed on the position support, connected with position adjuster directly, its main function is complete positioning 180°, adjusting the position adjuster from bottom to top, and swapping position of the bud and root. Because the position support is heavy, the eject motor of garlic clove changes speed through change gears, then connects with position support [11]. The eject motor of garlic clove make the position support drive the position adjuster to rotate a certain angle, and make the garlic clove fall down to the exit of garlic clove from position adjuster to accomplish recognizing and positioning.

There are two cases in position process. The first case is when the controller determines that the part of garlic clove below recognizer is the root, based on the information collected, then the eject motor of garlic clove rotates downward, makes the bottom of recognizer lower, so garlic cloves could slide out of the recognizer, fall into the exit of garlic clove, and start to plant, then the position motor and eject motor of garlic clove recover to the original position [12]. The other case is when the controller determines that the part of garlic clove below recognizer is the bud, the position motor rotates 180°, moves the position adjuster from bottom to top, swaps position of the bud and root, then the eject motor of garlic clove rotates downward, makes the bottom of recognizer lower, so garlic cloves could slide out of the recognizer, fall into the exit of garlic clove, and start to plant, then the position motor and eject motor of garlic clove recover to the original position [13].

3.3. The Composition and Implementation of Recognize and Control System

The position identification system of garlic clove is shown in figure 4, it is mainly composed of CCD imaging sensor, images acquisition circuits, controller and motor drive circuits. CCD imaging sensor, images acquisition circuits and position fixture accomplish image collecting together. The control segment centers on the singlechip of MC9S12XS128MAA, it completes information's compression and identification, and adjusts the information. The main function of images acquisition circuits is lowering the calculated load of singlechip, implementing hardware binaryzation of PAL signal, and conversing gray scale images into monochrome images by adjusting the threshold, so it is unnecessary to conduct A/D conversion to collect images, and make it possible to improve resolution. Besides image signal, camera vision signal contains horizontal synchronizing signal, horizontal synchronizing blanking signal, field synchronizing signal, field synchronizing blanking signal and so on [14]. The system implements video sync separating of the camera vision signal with chip LM1881, and gets odd and even field signal O/E and horizontal synchronizing signal IRQ. O/E signal is a square signal, its period is 40ms, the odd field is in the high electrical level, the even field is in the low electrical level, the program collects image signal of odd field or even field only. The IRQ signal is a square signal, its period is 64us, low electrical level marks the beginning of each line. Master chip of the control system is Freescale's 16-bit singlechip of MC9S12XS128MAA. We select First Technology's OV5116P dynamically Integrated CMOS camera, its signal processing circuit board integrates video separator LM1881, and electrical level signal LM393 which is converted analog signal into digital signal, it outputs 5 signal lines, they are lines of horizontal interrupt signal, field interrupt signal, image analog signal, image binaryzation digital signal, and image dynamic threshold mirror signal [15]. Number "1" stands for positive 5V, "2" stands for negative pole, "3" stands for image digital backward signal, "4" stands for image analog signal, "5" stands for image digital signal, "6" stands for mirror reference voltage signal (test only), "7" stands for horizontal interrupt signal, and "8" stands for field interrupt signal. Pins on the camera from left to right are: pin 1 is jointed with the positive pole of power, pin 2 is jointed with the negative pole of power, pin 5 is jointed with singlechip PT2, pin 8 is jointed with singlechip PT1. Pin 3 and pin

5 must be jointed with pull-up resistor of 2KΩ. So the singlechip of MC9S12XS128MAA and OV5116P CMOS camera can be connected directly.

Motor drive circuit uses BTS7970 motor drive module, 8 MOS forms H bridge circuit, and integrates drive circuit of drive field-effect tube, the drive circuit supports external drive power of 12V, and the two motor drive circuits are the same. PWM12 and PWM34 are used to output PWM control signal of position motor, PWM56 and PWM78 are used to output PWM control signal of eject motor, they are connected with drive circuit port respectively.

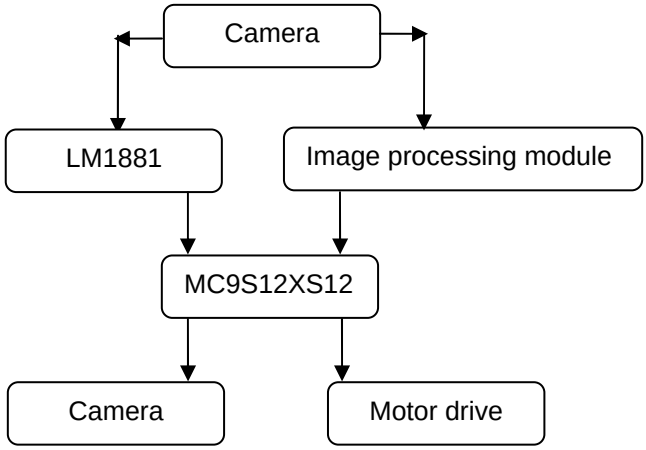


Figure 6. Figure of identificate and control system

4. Results and Analysis

The width of the recognizer is 2.5cm, the height is 2cm, and the length is 3cm, it is smooth inside, and the color is black. According to the feature of garlic clove, we conduct experiment on two conditions. One condition is dividing the garlic cloves into 3 classes based on the length of horizontal stem, class 1 is 2-2.5cm, class 2 is 1.5-1.99cm, and class 3 is 1-1.49 cm. The others are too small or too big to be planted, so we eliminate them. The result of the experiment is shown in table 1, only 16 of 300 well-chosen garlic cloves are not been identified, so it states that the method is effective. But when the length of horizontal stem is close to the width of recognizer groove, the rate of identification will decrease; when the length is too small, the rate of identification will decrease too; when the length is in the middle, the rate of identification is the highest. It illustrates that the change of identification rate is related to the width of recognizer groove and the length of horizontal stem.

Table 1. The Results of Classification Identification Experiment (cm)

	Experiment of Classification Identification		
Class（cm）	2～2.5	1.5～1.99	1～1. 49
Identification Number	89	95	92
Identification Rate	89	95	92

Another condition is dividing the garlic cloves in 4 classes based on the length of horizontal stem and shape of garlic cloves, the length of class 1 is 2-2.5cm and the shape is regular; the length of class 2 is 1.5-1.99cm, and the shape is regular; the length of class 3 is 1-1.49cm, and the shape is regular; the length of class 4 is 2.5-3cm, and the shape is irregular; the other are too small or too big to be planted, so we eliminate them. The result of the experiment is shown in table 2, only 11 of 300 shape-regular garlic cloves which were well-chosen are not been identified, 10 of 100 shape-irregular cloves were not been identified. So it states that the rate of identification of shape-irregular cloves will decrease. It illustrates that the rate of position identification is related to the length of horizontal stem and the shape of garlic clove.

Table 2. Experiment of Garlic Clove Identification (cm)

	Experiment of Garlic Clove Identification			
	Regular Shape			Irregular Shape
Class（cm）	2～2.5	1.5～1.99	1～1.49	1～2
Identification Number	92	97	94	87
Identification Rate	92	97	94	87

5. Conclusion

The paper proposed a position identification method of garlic clove based on machine vision; it elaborated the image processing method of self-adaptation and edge extraction, studied on the identification theory of local information collection, designed the identification device, developed the identification control system, and conducted a large number of experiments, the results demonstrated that the method can realize the position identification of garlic clove, and lay the foundation for the development of garlic planting machine. Yet the research plan is not completed, and the experiment is not adequate, it still needs to be studied further.

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