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A Low Cost 3D Acquiring System for Mushroom Robot Based on Webcam and Line Laser

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Abstract: This paper presents a low cost 3D acquiring system for mushroom robot based on webcam and line laser. The system comprises Webcam, semiconductor line laser, motion platform and data process unit. The system can get the 3D information of the Pleurotus eryngii in bottle based on structured light scanning theory. Field test shows the accuracy of the height is less than 2mm and it can be use to locate the buds in the bottle correctly. It has the potention to fulfill the requirement of the location of the mushroom for thinning bud robot. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: 3D acquiring system, Mushroom robot, Structured light.

1. Introduction

Pleurotus eryngii is the largest species in the oyster mushroom genus, Pleurotus, which also contains the oyster mushroom Pleurotus ostreatus. Pleurotus eryngii plays a very important role in the mushroom industry all over the world because of the high value of it. In an attempt to maintain a profit from decreasing prices, growers have reduced a number of costs including: raw material, energy, however labour costs have increased significantly. The contribution of labour to overall production costs for growers is generally at least 40 %.

Automation has the potential of improving the quality of fresh produce, lowering production costs and reducing the requirement of labour. Therefore automation may provide a solution to the issues of labour costs and skills availability, thus improving the competitiveness of farmers in the global supply chains. Mushroom industrial production has been applied in many companies to remain competitive.

Many researchers have carried out researches into the problems surrounding harvesting mushrooms mechanically. The result leads to the development of picking vision robots. But as for Pleurotus eryngii, thinning bud work is needed during the growth period to increase the yield. Only 2~3 mushroom buds which looks strong and big are kept, and other buds are cut away. Traditionally, the work is done by the worker with a knife, which is labor consuming and time costing.

Therefore, there is a strong desire to mechanize thinning bud process. However, detecting and locating the target mushroom buds in 3D space to control the robot is difficult due to the various different shape of the Pleurotus eryngii buds cluster in the 3D space. Fig. 1 shows a picture taken in Pleurotus aeryngii factory. It is obviously that the number of buds and the shape of bud are both variable.

Fig. 1. Picture of Pleurotus eryngii in bottle.

The disorderly growth of the Pleurotus eryngii in bottle makes it difficult to accurately recognize the cutting region through 2D picture. To mechanize thinning bud, the 3D structure information of the mushroomcluster is needed. There are many ways to get the 3D information, such as stereovision, 3D scanner et al [1]. A low cost 3D scanner method based on webcam and line laser was adopted here. This paper demonstrates a prototype of the 3D information acquiring system.

These techniques require complicated calibration procedures to get the parameters of sensors and projectors [2]. Camera calibration is carried out as the process of determining the internal camera geometric and optical characteristics and the 3D position and orientation of the camera frame relative to the world coordinate system. The purpose of the calibration is to establish a relationship between 3D points from the world and 2D points from the image acquired by the computer [3–5].

2. System Configuration

Fig. 2 presents the schematic setup of the low cost 3D acquiring system. The system comprises Webcam, semiconductor line laser, motion platform and data process unit. Webcam acquires the distortion picture of the target with the line laser was projected on it. The webcam used in this configure was a low cost webcam with pix of 480*360 and framerate of 30 fps. The semiconductor line laser produces a continuous line laser with the wavelength at 635nm and the average power of 10mW. Motion platform is composed by step motor, motor controller and linear slide. The motion platform travels at a constant velocity to produces a push broom movement between line laser and the target. In practical application, the platform can be replaced by the conveyer belt which is used to transfer the bottles. Data process unit is a computer which can acquire the picture from the webcam through the USB port. The data process software is running on it and products the point cloud file at last. Fig. 3 demonstrates the prototype of the 3D acquiring system used in the laboratory test. The line laser is installed on the top of the linear slide with the direction vertical to the linear slide. The webcam is focus to the target and the direction of optic axis is tilt to the target. Motor controller has the function of adjusting the speed of the motor. In order to facilitate the experiment, we set the linear slider in the to-and-fro movement mode.

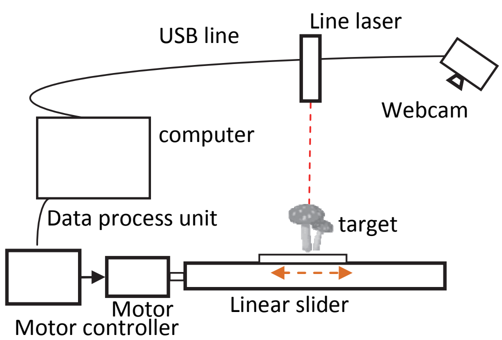

Fig. 2. Schematic setup of the 3D acquiring system.

3. Methods

3.1. Camera Geometry Model

Most of the procedures used for camera calibration are normally based on the pinhole camera model. The pinhole camera model describes the mathematical relationship between the coordinates of a 3D point and its projection onto the image plane of an ideal pinhole camera, where the camera aperture is described as a point and no lenses are used to focus light.

As Fig. 3 shows, we draw an easy camera model for the current configuration. O is the optical center of the camera. The line A2O2 locates on the image plane of the camera. OO2 is the focal length and OO1 is the optical axis.

In this easy model the height of O1A1 can be calculated according to the triangulation. O1O3 and OO3 are the extrinsic parameters of the camera which can be measured by the user, OO2 is the internal parameter of the camera, O2A2 is the laser line information we got from the webcam.

We define the direction of target movement as Y, and the direction which vertical to Y as X. The height direction is defined as Z. It is easy to know that the same height in different Y has the same x-offset in image. So we can calculate the height only according to the x-offset in the image.

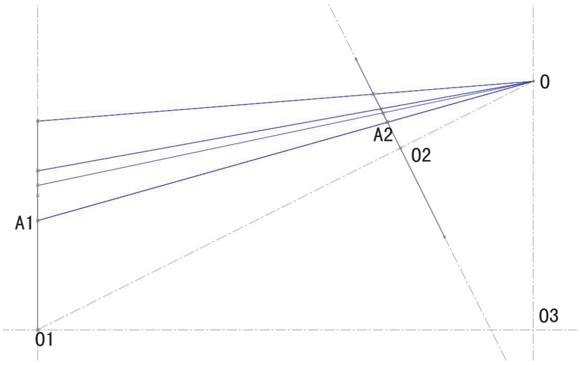

Fig. 3. Calculate the height according to the triangulation.

$$Z = f\left(x_{offset}\right), \tag{1}$$

In the full camera geometry model diagram (Fig. 4), we can also know that the different Y with same height has the same Y and y-offset ratio. So we can calculate the height first, then calculate the Y and y-offset ratio according to height(or x-offset), then Y is determinated by y-offset and ratio.

$$Y = ration \times y_{offset}, \tag{2}$$

$$ration = f\left(x_{offset}\right), \tag{3}$$

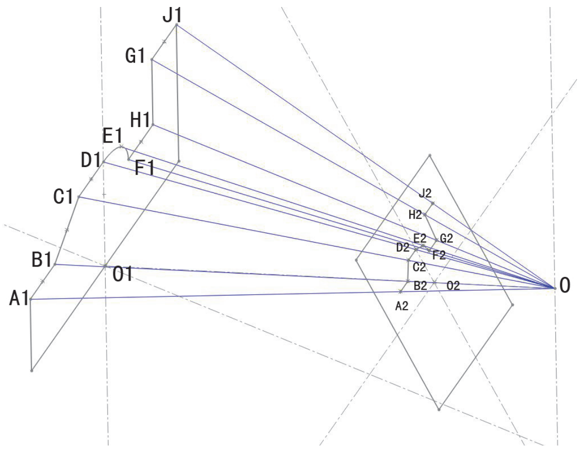

Fig. 4. Full Camera Geometry Model.

Due to the low accessibility of the internal and extrinsic parameters of the camera, all the Calculations were through the numerical calibration using Quadratic polynomial. First place some standard blocks which size was measured before. Then the x and y offset can be acquired from the software system built by ourselves. Last we use the data to estimate the parameters in equation (1) and (3) using the Quadratic polynomial model. With the equation (1)-(3) the Y, Z can be calculated with the x offset and y offset acquired from the software. The X step can be calculated from the equation (4), and in the equation velocity of the motor and the time interval are the basic parameters of the system.

3.2. Camera Calibration

Since the image captured from the camera was distortion due to the distortions of the lens. The main distortions include radial and tangential distortions. It is important to eliminate the distortions in the area of the computer vision.

The theory of the camera calibration was described in section 3. We used the calibration functions in the OpenCV to get the distortion parameters and correct distortions in the images [7-9]. After the calibration, parameters R (rotation matrix) and T (translation vector) were defined.

3.3. Image Processing

Open CV (Open Source Computer Vision Library) is a library of programming functions mainly aimed at real-time computer vision, developed by Intel, and now supported by Willow Garage and Itseez. It is free for use under the open source BSD license. The library is cross-platform. It focuses mainly on real-time image processing. In our project we use Visual C++ as the software platform and Open CV as the image processing library [6].

Firstly, the image was captured by the software through the functions of Open CV. Then the color image was converted to grey image. Because the scatter light of the target, the laser line is rather thick and blur. It was hard to get the center line through global threshold because the density of the laser line was not uniform through the line, so we blurred the grey image using the Gaussian kernel and then got the center line of the laser.

Then the index of the max bright pixel, i.e. IndexOfMaxVal was needed to be confirmed. The subpixel center point was calculated according to the point index from IndexOfMaxVal-10 to IndexOfMaxVal+10. The algorithm is like (4):

$$centerIndex = \frac{\sum_{i=indexFrom}^{indexTo} i \times grey(i)}{\sum_{i=indexFrom}^{indexTo} grey(i)}, \tag{4}$$

where grey (i) means the pixel grey value of the point in the column i.

At last, line interpolation was done to get the left points. Fig. 5 shows the original image (left) and the processed image (right) with the center line has been picked up.

Fig. 5. Gaussian Blur and subpixel center line.

3.3. Field Test

In order to assess the accuracy of the system, and to evaluate the suitability of the system for field operations, we organized a field test in the laboratory of College of Engineering, China Agricultural University. The bottle with Pleurotus eryngii was supported by the factory. Before the test, all the lights were turn off and the room was dark. Firstly, camera calibration was carried out to get the rotation matrix and translation vector of the camera. Secondly, a set of measurements of the calibration (height and length) was performed using the system developed. The measurements were made with the stepper placed in different points of the image, with special incidence on the image borders, because those were the regions of greatest distortion. The result of the calibration defined the parameters of the system. Thirdly, we carried out the scanning of the Pleurotus eryngii. When we get the point cloud file, we open it in MeshLab which is an advanced 3D mesh processing software system focus on 3D development and data handling.

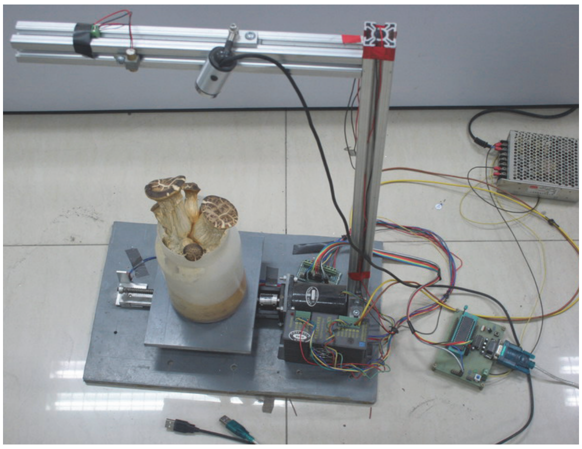

Fig. 6. Prototype of the 3D acquire system used in the laboratory test.

4. Results and Discussion

Fig. 7 demonstrates the performance of the 3D acquiring system. The accuracy of the height is less than 2 mm. The accuracy of the length in the horizontal plane is less than 3 mm. This system can fulfill the requirement of the location of the mushroom thinning bud robot.

Webcam and semiconductor line laser are chosen as the core of the system. Both of them have the advantage of low cost. As for the data process software, the adoption of free Open CV makes it an easy work.

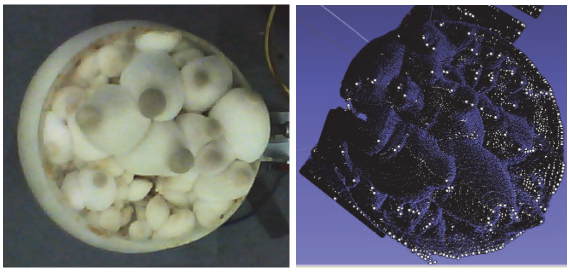

Fig. 7. Test result of the system.

The shortages of the system are as following:

1) the process is too slow, the calculation process costs about 0.5 s for every image, so the calculation process need more optimization;

2) the occlusion problem, which occurs when the camera is not capable of visualizing the laser beam reflected by the mushroom, due to the object geometry. To overcome this limitation, it is common to use a second camera;

3) a lot of calibrations are needed, such as camera calibration and system calibration.

There are some more advanced 3D scanners based on low-cost webcam such as DAVID-laser scanner and Vi3Dim. In the future work, we plan to adopt new method to improve the processing speed. To overcome the shortcoming of slow speed, multiple systems which work together coordinately will be adopted in the future work.

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