3D Point Cloud Registration of Sugarcane Based on KinectV2 Depth Sensor

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Abstract: In order to more accurately establish the three-dimensional point cloud model of sugarcane, so as to more effectively analyze the structure of sugarcane. KinectV2 depth sensor was used to obtain sugarcane point cloud data from different perspectives. In order to solve the problem that the traditional Iterative closest point algorithm (ICP) is demanding the attitude of space, an improved method is proposed. Firstly, the point cloud was preprocessed to remove redundant background and noise, and then the initial registration and accurate registration are carried out. The Normal Aligned adial feature algorithm (NARF) was used to search the point cloud. The fast point feature histogram (FPFH) was used to calculate the feature vectors corresponding to the key points. The sample consensus initial alignment algorithm (SAC-IA) was used to find the key points with similar FPFH characteristics in the point cloud. The correspondence between points was constructed and the rotation translation matrix was calculated, Initial registration was completed by rotating translation point cloud. Experimental results show that the error of the proposed algorithm is 2.64cm lower than that of the ICP algorithm, which can effectively improve the robustness and accuracy of the point cloud registration.

1. Introduction

Sugarcane is a temperate and tropical crop. It is the raw material for making sucrose and can be used to extract ethanol. China is a large sugarcane growing country, and its sugarcane production ranks third in the world. The phenotypic characteristics of sugarcane reflect the growth state of sugarcane to a certain extent and are closely related to the yield of sugarcane. By using the 3D point cloud technology to establish an accurate 3D characteristic model of sugarcane, the corresponding sugarcane characteristic parameters can be extracted from the point cloud, so as to scientifically and effectively guide sugarcane cultivation to increase sugarcane yield. In a single perspective, affected by the crop's spatial position, geometry, environment, and equipment itself, it cannot fully reflect the true situation of the crop. Therefore, the crops need to be scanned from different angles, and the local point cloud of each scan was transformed into a unified coordinate system through the coordinate relationship between them. This process was called point cloud registration[1]. At present, the common methods for obtaining three-dimensional point clouds of crops are: laser scanning method, binocular vision method, and so on. Documents [2-4] used binocular vision to build a three-dimensional model of the crop and measure the corresponding parameters of the crop. However, in the complex field environment, the binocular vision method has the problems of weak anti-interference, low matching accuracy, complex algorithm and slow processing speed. Articles [5-7] used laser scanning to conduct 3D modeling of plants. Although the laser scanning method has high measurement accuracy, it was expensive and not suitable for small farmers, and requires a lot of manual interaction. The second generation Kinect, KinectV2 sensor, can capture color and depth images of the scene in real time. It uses Time of Flight (ToF) active light source technology and was not easily affected by changes in external light. At present, a large number of scholars at home and abroad have applied KinectV2 to the field of agricultural researches[8-10].

In this paper, KinectV2 sensor was used to collect point cloud information of sugarcane plants from different angles and heights. The initial point cloud registration was performed first, and then the ICP algorithm was used for accurate registration. The accuracy and stability of point cloud registration were improved, and the precise stitching of sugarcane point clouds at different angles was achieved.

2. Materials And Methods

2.1 Sugarcane Point Cloud Collection

The sugarcane plants were planted individually in buckets in an experimental station located in Fusui County, Guangxi Zhuang Autonomous Region Five plants with different varieties were randomly selected to capture their RGB images as well as depth images with Kinect V2 sensor Dell Precision7530 mobile workstation (Intel-i9CPU, 32GB high-speed memory, NVIDIA Quadro P2000 graphics card) was used to store and process the data. The main parameters for KinectV2 are shown in table 1. The software development kit, Kinect for Windows SDK, was used to provide APIs combined with PCL1.81, the RGB images and depth images were fused to obtain three-dimensional coordinate data with color information in the camera space coordinate system [11].

Table. 1 Parameters of the KinectV2 sensor

parameter	The numerical
RGB color image resolution	1920×1080
Depth (infrared) image resolution	512×424
Frame rate (FPS)	30fps
Horizontal field of view	70°
Vertical field of view Angle	60°
Detection range	0.5～4.5m

2.2 Point cloud preprocessing

The original point cloud collected by kinect contains redundant background information and unstable noise points due to environment, equipment and human factors. Therefore, effective background removal and noise filtering and noise reduction pretreatment are needed for the original point cloud to obtain the point cloud data containing only a single sugarcane plant.

Based on the 3D coordinate information of the scene, the background information of sugarcane can be removed well. According to the actual sugarcane point cloud data, a three-dimensional coordinate value range is set, and point clouds outside the value range are regarded as the background and removed.

This article used statistical filtering to remove point cloud noise[12~13]. Statistical filtering refers to finding the average distance between this point and other points in the k field for any point. It was assumed that the distribution of the obtained results roughly follows a Gaussian distribution. The mean μ and standard σ deviation of the Gaussian distribution can be calculated, keeping the average distance within the range $(\mu - \sigma, \mu + \sigma)$.

2.3 Point cloud registration

Scholars at home and abroad have done a lot of research and exploration on point cloud registration. Among them, the most classical algorithm is the iterative nearest point (ICP) algorithm first proposed by p.j. besletal[14]. The registration accuracy and running speed of the algorithm were largely determined by the initial position and number of point clouds. When the initial pose was close and the number of point clouds was small, the registration accuracy of ICP algorithm was high and the operation speed was fast; When the initial pose difference was large and the number of point clouds was large, the algorithm takes a long time to calculate and easily falls into a local optimal solution. This paper proposed an initial point cloud registration method, which enables two point clouds to obtain a closer spatial position through initial registration, and further used the ICP algorithm to accurately register the point cloud. First, the normalized aligned radial feature NARF key points were searched for the obtained point cloud information of sugarcane plants to obtain a representative and relatively uniform point cloud key point[15]. Secondly, calculate the eigenvectors of the fast point feature histogram (FPFH) of the key points[16]. The third point is to use the Sampling Consistent Initial Registration[17] Algorithm (SAC-IA) to find the key points with similar FPFH characteristics, use these similar points to build the correspondence between points, and calculate the rotation translation matrix. Initial registration is accomplished by rotating and translating the point cloud. The initial registration flowchart of sugarcane point cloud is shown in Figure 1.

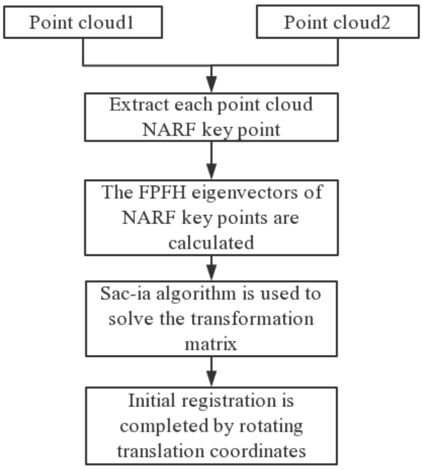


Fig.1 Point cloud initial registration flowchart

The purpose of using NARF key point search points was to reflect the overall point cloud characteristics with a small number of point clouds, thereby reducing the search time and calculation time in FPFH feature extraction. When searching for keypoints, it was also necessary to ensure that keypoints can be detected at the same location of the two point clouds.

FPFH was used to solve the eigenvectors of key points. FPFH calculates the relationship between the normal of the keypoints and the points in the k domain to estimate the magnitude of the change in the sample surface, and generates a histogram for feature description. The algorithm is simple, fast and descriptive.

Sample consensus initial aligment algorithm (SAC-IA) compares the similarities of the FPFH features of the key points of the two point clouds and finds out one-to-one correspondence with key points with similar FPFH features. Rigid body transformation was performed after calculating the corresponding point rotation and translation matrix.

Accurate registration of sugarcane point cloud using ICP algorithm. The ICP algorithm is an algorithm that gradually approximates the optimal solution through repeat iterative calculations. Because this paper has already performed the initial registration and uses the ICP algorithm again for accurate registration, it will not fall into the local optimal situation, and can achieve a good registration effect. At the same time, in order to ensure the efficiency and accuracy of registration, the two point clouds need to have a certain amount of common parts.

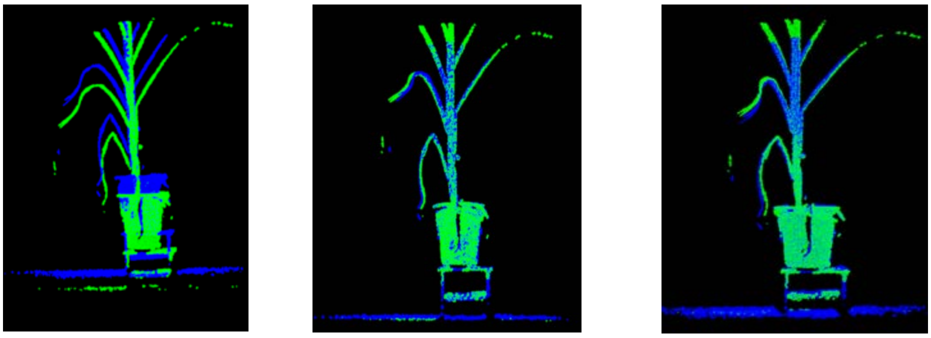
3. Resuits And Analysis

3.1 Point cloud preprocessing and point cloud registration

The Kinect original 3D point cloud contains unstable noise points and some redundant background information. The original 3D point cloud needs to be preprocessed by background removal and related filtering and noise reduction to obtain an effective point cloud registration Point cloud data. The processed point cloud image was shown in Figure 2.

Fig.2 Point clouds after preprocessing in different perspectives

By extracting the NARF key points of each point cloud and calculating the corresponding FPFH feature vector, the SAC-IA algorithm was used to compare the FPFH similarity between the key points to obtain the corresponding spatial mapping relationship to complete the initial registration of the point cloud. Finally, the ICP algorithm was used for accurate registration. Figure 3 shows the whole process of 2 point cloud images from initial registration and precise registration. From Figure 4(a), it is shown that the position of the two point clouds is very different. Through the initial registration of the point cloud, the two point clouds basically match, but in some details, the registration is not in place, and there is a certain error, as shown in Figure 4(b). Figure 4(c) is an image of the point cloud after precise registration. The details of registration optimization were further completed on the basis of coarse registration, so that the registration results meet the requirements of registration more accurately.



(a)Original point cloud (b) Initial registration result (c) Accurate registration results

Fig.3 Results of initial registration and precise registration of the point cloud

3.2 Point cloud registration error analysis

For quantitative analysis of point cloud registration, the average Euclidean distance between corresponding points was used as the evaluation criterion for point cloud registration errors. A smaller average Euclidean distance indicates higher registration accuracy. By comparing the error between this algorithm and traditional ICP algorithm, the results are shown in Figure 5 and Table 2.

(a)Original point cloud (b) ICP Registration algorithm (C) Registration algorithm in this paper

Fig.4 Image comparison of different point cloud registration algorithms

Table.2Point cloud registration error analysis

Registration method	Registration error/cm	Registration time/s	Number of point clouds
ICP registration algorithm	3.42cm	66.3s	78230
Registration algorithm in this paper	0.78cm	187.4s	78230

4. Conclusion

The point cloud preprocessing effectively filters out the point cloud noise and redundant background information, and obtains more accurate sugarcane point cloud data.

Under the premise of the traditional ICP registration algorithm, the initial registration was completed by extracting NRAF key points, calculating the FPFH feature vector and the SAC-IA algorithm to extract the corresponding relationship, and then performing ICP accurate registration greatly improves the accuracy of registration.

Since the initial registration was introduced in this algorithm, the time of the registration algorithm was prolonged. Later, more efficient algorithms can be explored to reduce the processing time of the registration algorithm without reducing the accuracy.

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