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A precision pose measurement technique based on multi-cooperative logo

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Abstract: The use of image recognition technology to complete the precise pose measurement of objects has always been a difficulty in the field of computer vision. This paper proposes a precision pose measurement technology based on multi-cooperation logo, which uses OpenCV and Aruco to complete the generation of cooperative logo. Through the uPnP algorithm to complete the relative pose detection of the camera and the cooperation logo, and then the precise pose measurement of the multi-cooperation sign is completed by Gaussian filtering and iteration of the nearest neighbor. Compared with the traditional positioning method, it has higher accuracy and robustness. This technology has important reference value in robot positioning.

1. Introduction

The indoor autonomous mobile platform is affected by factors such as small indoor space and complex environment, and it is generally impossible to use satellite positioning matters for robot positioning and attitude estimation. Autonomous mobile platforms often use lidar to obtain a map of the surrounding environment, and then carry out positioning and attitude estimation for themselves and indoor environment, but this method has accumulated errors. At the same time, because the price of lidar is more expensive, it will also increase the hardware cost of the autonomous mobile platform, not conducive to the development and engineering of later products. Therefore, building low-cost hardware development platforms is attracting more and more attention. In the recently proposed indoor pose estimation of autonomous mobile platforms, the use of computer vision and cooperative identification to estimate the pose of objects has gradually become a research hotspot ^[1]. However, the use of visual sensors to capture video to achieve the pose estimation of target objects is susceptible. The complex background, illumination transformation, and obstruction and other factors cause the inaccurate pose estimation. How to accurately estimate the pose of the target object under the interference of complex environment and other factors? This problem is the focus of research on indoor autonomous mobile platform attitude estimation.

The vision sensor selected in this article is a monocular vision sensor, which is a C925E vision sensor independently developed by Logitech, which can provide 30f/s 1920×1080 high-quality video information. In order to solve the problem of cooperative logo selection for autonomous mobile platforms, most researchers choose the Aruco AR logo system. In 2013, Schmid et al. applied the indoor Hamming code fiducial mark system to the indoor positioning of the quadrotor UAV ^[2]. Although the UAV can be effectively positioned and attitude estimated, the system has high latency. Later researches used AR markers as spatial recognition markers ^[3-5]. In this paper, inspired by Schmid et al. ^[3], the ArUco mark ^[6] in AR technology is used directly in the pose estimation of the target object, and the



C925E vision sensor is used to measure the target with the cooperative logo. By positioning and posture estimation of the ArUco marker, and then through coordinate transformation, the position and attitude of the autonomous mobile platform relative to the cooperative marker with known pose are obtained. Through the positioning and pose estimation of the ArUco markers, the posture of the target object relative to the camera is obtained through coordinate transformation.

In this paper, by improving the ArUco labeling algorithm, a positioning and attitude estimation algorithm based on multi-cooperative Peugeot is proposed. Compared with the traditional single cooperation logo pose estimation method, its positioning accuracy and data robustness have been significantly improved.

2. Location and attitude estimation based on cooperative identification

Any sensor has certain defects in the pose estimation process, The use of contact sensors such as lidar and inertial measurement software will produce errors that will gradually increase with the accumulation of data. If there is no later correction, The measurement result will seriously deviate from the true value. The visual sensor in the touch sensor is limited by hardware, and the frame rate of visual acquisition is significantly lower than that of the touch sensor. Therefore, in the visual tracking method, in order to directly obtain the pose of the camera relative to the ArUco logo, this paper adopts two methods, the traditional single cooperative logo algorithm and the improved multi-cooperative logo algorithm, to estimate the pose of the target object, and compare the experimental results. The camera coordinate system is composed of X_c , Y_c , and Z_c axes. With the focus of the C925E camera as the center, the coordinate origin of the camera coordinate system can be converted to the origin of the cooperative identification coordinate system through coordinate transformation. The image coordinate system is composed of two coordinate axes as u , v constitutes a two-dimensional plane coordinate system, the coordinate system represents the pixel size of the object in the imaging plane. The coordinate logo coordinate system describes the spatial coordinates of the camera relative to the logo.

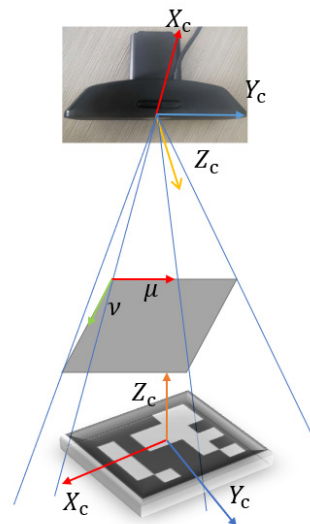


Figure 1. Schematic diagram of the coordinate system.

2.1. ArUco mark detection

As shown in Figure 2, the ArUco mark is a binary mark originally proposed by Rafael Munoz and Sergio Garrido, and is mainly used in the field of augmented reality and visual measurement.

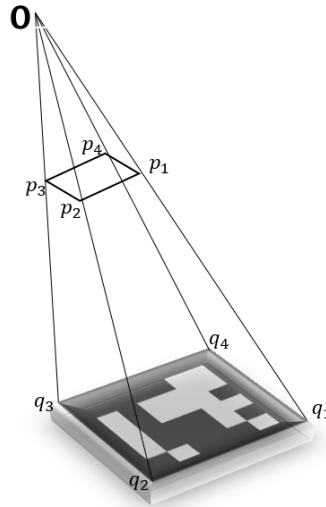


Figure 2. Schematic diagram of ArUco mark detection.

Considering the unique recognition of the ArUco mark, it is easy to identify and match in the pose estimation process based on the cooperative logo. However, a single ArUco is prone to data jumps and loss during the detection process. Based on the above problems, this paper has designed a pose estimation method based on the ArUco library for multi-cooperative identification, and compared with the traditional ArUco pose estimation method analysis.

2.2. Algorithm theoretical analysis and design

The traditional ArUco pose estimation method and the multi-cooperative logo based on the ArUco library are both based on the robust plane pose (Robust Planar Pose, RPP) algorithm^[7] [14]. The goal of positioning the autonomous mobile platform is achieved by estimating the pose of the logo plane. The perspective transformation of the image is as follows:

$$s * p_i = A[R_G|T_G]q_i \quad (1)$$

The symbols in the formula are defined as follows: s is a scale factor, p_i is any point on the image, and q_i is the 3D coordinate of the camera coordinate system corresponding to p_i on the image. Due to the process problems of the camera during the production process, there is a certain distortion in its image quality. Matrix A represents the internal parameters of the camera and the relationship between the camera coordinate system and the ideal coordinate system without image distortion; $[R_G|T_G]$ is called the camera external parameter, which means the direction and pose of the camera in the world coordinate system, R represents the rotation matrix, and T represents the rotation matrix. Formula (1) is further developed to obtain formula (2):

$$T_z \begin{bmatrix} \mu \\ \nu \\ 1 \end{bmatrix} = \begin{pmatrix} f_x & 0 & \mu_0 \\ 0 & f_y & \nu_0 \\ 0 & 0 & 1 \end{pmatrix} \begin{bmatrix} r_{11} & r_{12} & r_{13} & t_1 \\ r_{21} & r_{22} & r_{23} & t_2 \\ r_{31} & r_{32} & r_{33} & t_3 \end{bmatrix} \begin{bmatrix} X_G \\ Y_G \\ Z_G \\ 1 \end{bmatrix} \quad (2)$$

The internal reference A of the camera in equation (1) can be obtained by the OpenCV camera calibration tool. The calibration method used in the calibration tool is the Zhang Zhengyou calibration method: f_x and f_y in A represent the focal length of the camera in both the x-axis and y-axis directions.

ArUco marks the image as a square, which requires three-dimensional position information corresponding to the four corners of the square^[8]. In this paper, the logo is pasted on a smooth wall surface, and the lower left corner of the logo is defined as the origin of the coordinate logo coordinate system. Since the position relationship of the four corner points of the logo is known, the four corner points can be used in the two-dimensional coordinates of the image coordinate system Information, using the solvePnP algorithm in the OpenCV processing method^[9], we can get the rotation matrix R and

translation matrix T . The solvePnP function uses the algorithm as the n-point projection method^[10]. The 12 unknowns calculated by this method are stored in the form of rotation vectors. The rotation vector is converted into a 3×3 rotation matrix R through the Rodrigues conversion equation, and then the external parameters (rotation vector and translation vector) of the camera relative to the cooperative logo. The Euler angle of the camera relative to the cooperative logo is calculated by formulas (3), (4) and (5), and then the three-dimensional position of the camera relative to the cooperative logo is obtained.

$$\theta_x = \arctan2(r_{32}, r_{33}) \quad (3)$$

$$\theta_y = \arctan2(-r_{31}, \sqrt{r_{32}^2 + r_{33}^2}) \quad (4)$$

$$\theta_z = \arctan2(r_{21}, r_{11}) \quad (5)$$

θ_x , θ_y , θ_z represent pitch angle, yaw angle and roll angle, respectively. A three-dimensional coordinate system of the camera coordinate system is convenient for later data comparison. The traditional ArUco positioning and attitude estimation methods are prone to data jumps and reading failures, which makes the program unable to estimate the pose. In view of the above situation, this paper uses the above-mentioned pose estimation method as a theoretical basis to design a position and attitude estimation method based on multi-cooperative identification. The algorithm flowchart is shown in the following figure3:

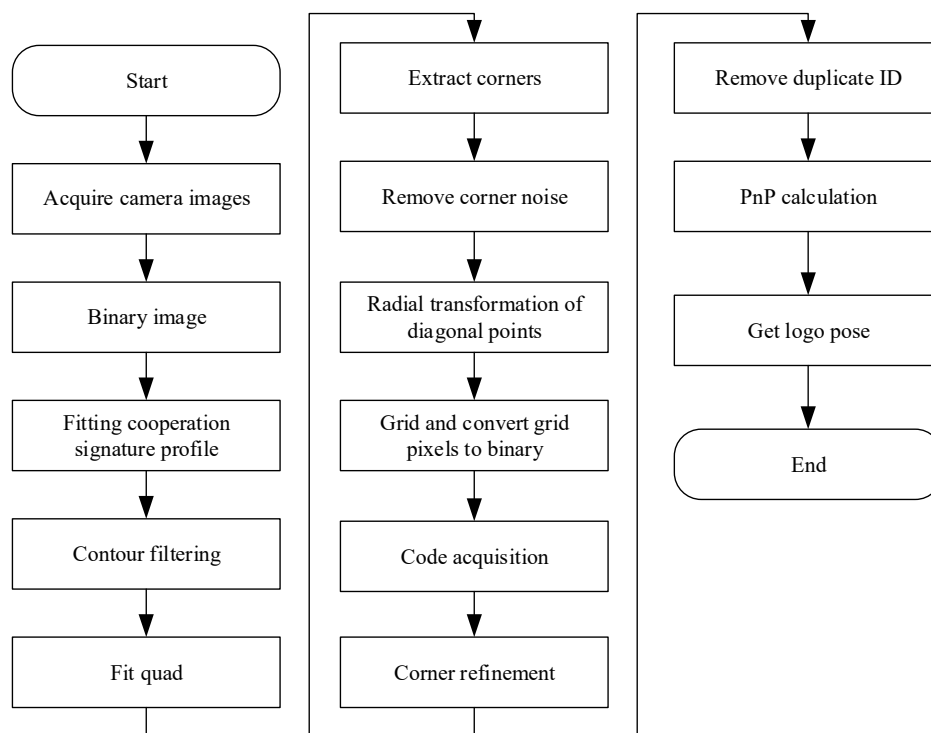


Figure 3. algorithm flow chart.

In this method, multiple cooperative signs are used to restrict their positional relationship. The corner information of the multiple cooperative signs is obtained through the corner extraction algorithm. Through data storage iterations, multiple frames of data are evaluated and calculated, and those with excessive jumps in the data are eliminated. Value, average calculation of multi-frame data.

3. Comparison of experimental process and results

The computer hardware used in this article is an Intel i5 eight-generation CPU, 8G RAM. The development platform uses the visual studio 2015 software of the window10 system, combined with C++ and OpenCV language to complete the development of software algorithms.

In order to verify the accuracy and robustness of the traditional ArUco identification method and the method based on multi-cooperation identification, this paper designed an experiment as follows: in the same environment and the same pose, using the traditional single cooperation logo and multiple cooperation logo measurements Pose in the same state.



Figure 4. Estimation of the pose of a single logo.



Figure 5. Estimation of poses of multiple signs.

The distance D_x , D_y , D_z and angle data θ_x , θ_y , θ_z in the three directions of X, Y and Z obtained by this experiment are converted by formulas (6) and (7) to obtain the actual distance D and actual distance of the camera from the cooperation logo Angle θ :

$$D = \sqrt{D_x^2 + D_y^2 + D_z^2} \quad (6)$$

$$\theta = \sqrt{\theta_x^2 + \theta_y^2 + \theta_z^2} \quad (7)$$

Through the comparison and analysis of the data in Figure 5, it is found that the true angle under the experimental conditions is zero degrees, and the data measured by the traditional single cooperative logo deviates greatly from the true value. The measured data interval is $[-0.78, -1]$, and the average value of the measurement is -0.84mm , the standard deviation is 0.03 . The measurement angle data obtained by the measurement method designed in this article is in the range of $[-0.5, 0.1]$, the measured average value is -0.06mm , and the standard deviation is 0.07 . Compared with the measurement of a single standard, the angle obtained by the multi-cooperative logo measurement The accuracy of the data has been greatly improved, but its data stability is poor and the robustness is not strong.

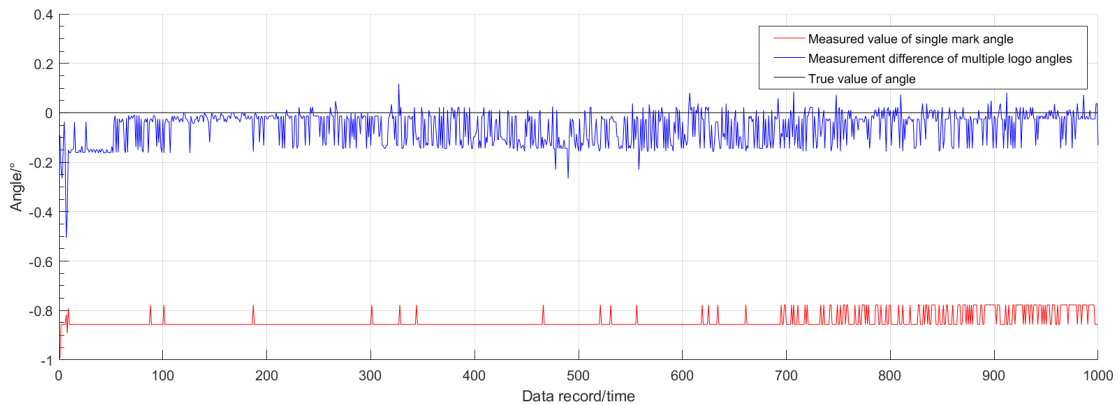


Figure 6. The experimental data of measured angle data.

The distance data obtained through comparative analysis and measurement in Figure 6 found that the true value of the distance was 58 mm . The data interval calculated using the traditional single cooperative logo is $[60, 61.2]$, the mean is 60.13mm , the variance is 0.9 , which is quite different from the real data, but the data interval obtained by using the multi-cooperative logo measurement algorithm designed in this paper is $[56.4, 56.8]$, the mean is 56.64mm , and the standard deviation is 0.21 . The overall mean of the data is closer to the true value, and the dispersion of the data from the mean is lower.

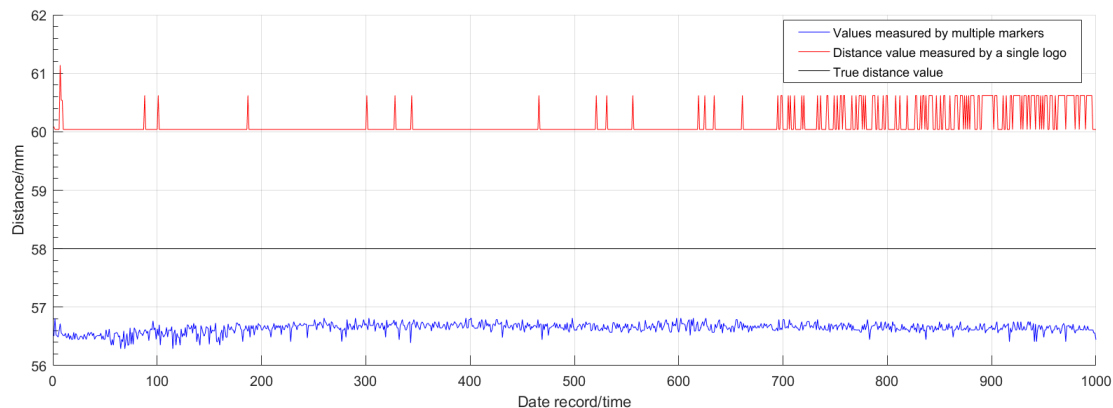


Figure 7. Distance measurement data chart.

4. Conclusions

In this paper, through theoretical analysis and experiments, the traditional cooperative logo positioning method has the disadvantages of large positioning error and poor robustness, and a new precision pose measurement technique based on multi-cooperation is designed. Through experimental testing and data analysis under the same environment, we found that the overall data reliability and robustness of the improved pose measurement data have been significantly improved, and the experimental results have reached expectations. The method designed in this paper has the effect of obtaining the cooperation logo position and pose efficiently, stably and accurately.

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