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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Stereo vision camera is widely used in the robotics area for terrain mapping, object detection, object classification, navigation, self-localization and so on. This thesis presents the problems that a Humanitarian Demining Robot Gryphon meets in the field when a stereo vision camera is used for terrain mapping: accurate Kinematic calibration and Hand-Eye calibration and ensuring the 3D terrain model still could be well acquired with a stereo vision camera even in the extreme light conditions. These problems are also the common and important issues when applying stereo vision camera in field and this thesis focuses on them.

Chapter 1 gives the background of the research and the related work is presented. Through a sequence of pure rotations of the manipulator links, the Kinematic calibration and Hand-Eye calibration could be performed simultaneously. Previous methods do not have a good performance when the joint motion that can be measured is limited by the Field of View of camera, and/or no external sensor is available, which is the case studied in this thesis. Through multiple exposures, the dynamic range of images could be increased. With the resulting fused images, the 3D terrain model is calculated through stereo matching. However, it is possible that some information is lost when the images are fused with exposure fusion and the stereo matching result with the fused images is not as good as expected.

Chapter 2 introduces the proposed Kinematic calibration and Hand-Eye calibration method, Pure Rotation through Fitting Circular Arc in 2D Space with Joint Angle Constraint. A self-calibration scheme using the stereo vision camera already included in the Gryphon platform was introduced. The Kinematic calibration and Hand-Eye calibration were performed simultaneously. The introduced calibration methodology relies on a sequence of pure rotations of the manipulator links, while tracking the manipulator's tip and an external arbitrary fixed reference point by the stereo vision camera. The new method considers an additional joint angle constraint to fit a circular arc, which improves the calibration accuracy especially when the circular arc that can be measured by the stereo vision camera is very limited. Experimental results using a manipulator developed for humanitarian demining demonstrate that with the proposed method the relative errors between the end effector and the external points mapped by the stereo vision camera are greatly reduced.

Chapter 3 presents the proposed Hand-Eye calibration method, Pure Rotations through Directly Fitting Circular Arc in 3D Space with Joint Angle Constraint. In the literature, the method that uses a sequence of pure rotations through the pan motion and tilt motion was presented for Hand-Eye calibration. However, the calibration accuracy degrades when the circular arc detected by the stereo vision camera is quite limited. A new method, which solves this problem by adding a joint angle constraint and directly fits a circular arc in 3D space, is

introduced. Compared to the traditional methods, simulations results showed the improved performance of the proposed methods, and experimental results using a Pan-Tilt-Camera system confirmed that with the proposed methods a better calibration result can be obtained.

Chapter 4 introduces the method of Terrain Mapping under Extreme Light Conditions with Direct Stereo Matching Algorithm. Through multiple exposures, the dynamic range of images could be increased. Since it is possible that the camera is moved when the images are grabbed with multiple exposures, the images grabbed with short and long exposures were aligned to the image captured with auto exposure. In this thesis, instead of using existing lighting enhancement methods such as exposure fusion to increase the texture of 2D image, the stereo matching is directly done using the images captured with multiple exposures and the matching costs of the images grabbed with multiple exposures are directly summed by weight. Compared with the previous methods such as exposure fusion, it is not needed to fuse the images grabbed with multiple exposures, and for each pixel of the matching image the local information in its local window acquired from the images grabbed with multiple exposures could be better retained. In order to evaluate the performance of the proposed method, two different stereo matching algorithms were used: a local window-based method and semi-global method. Through the experiments in laboratory and outdoors with a stereo vision camera fixed on a tripod and held in the hand, it was verified that the proposed method consistently allowed more valid points to be obtained and the 3D terrain model could be built more accurately. Especially when the local window-based method was used, the proposed method performed much better than the traditional methods.

Chapter 5 shows the conclusion of this thesis. A summary of the achievements and the future work are presented. Field experiments are planned to be conducted with the Gryphon system in Angola in the near future to further evaluate the proposed methods. The proposed methods can be used in other robot platforms.