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Article / Book Information

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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 ）

Visual odometry is an important research direction for applications such as autonomous driving. In this paper, firstly, we introduce how to build a stereo camera suitable for visual odometry systems, then we focus on the improvement of direct visual odometry methods.

In Chapter 1, we introduce mainstream visual odometry methods and point out the problems with existing methods.
The methods of visual odometry mainly include the feature points-based methods and the direct methods. the feature points-based methods can obtain high accuracy in the high texture area, but it is time-consuming and the reconstructed map is sparse. The direct methods do not need to extract feature points, which makes them have lower time consumption and better adapt to low texture areas, but they are weak to exposure changes.
Both the feature points-based methods and the direct methods can be implemented with a monocular camera or a stereo camera. In general, algorithms using stereo cameras are substantially more accurate and robust than comparable methods using monocular cameras. However, there are not many mature stereo camera products on the market. In our research, we designed a stereo camera and gave out some supporting software tools for mass production and ease of use by others.
Since the direct method is very sensitive to changes in exposure, we proposed a photometric calibration method for the stereo direct visual odometry.
Although the selection of key points in the direct method is not as strict as that in the feature points-based method, the point selection strategy may still affect the accuracy of the results. We proposed a new point selection method for direct visual odometry. Pixels on straight lines and long smooth edges are preferred in our method.

In Chapter 2, we give analysis and solutions to various problems in the design of camera manufacturing.
The binocular images provided by the stereo camera can bring great help to the visual odometry methods. Since the stereo cameras on the market are not very mature yet, we give out a set of processes for designing stereo cameras.
Our camera has a high resolution and high frame rate with the global shutter. We also add a nine-axis IMU to the camera. This makes our camera suitable for visual odometry.
We designed a calibration tool that displays a chessboard on the display. The tool automatically captures pictures and calibrates. The calibrated parameters are automatically saved to the camera storage. The additional parameter file is not needed even if the camera is used on different computers. The calibration tool for IMU is also developed.
We designed a tool to ensure that the focal planes of the two lenses in the stereo camera are consistent when installing the lens.
We also made tools to detect dust on sensors and tools to detect image stability.

In Chapter 3, we discussed the photometric calibration of stereo cameras in the direct method for visual odometry.
There are already many methods for calibrating the photometric properties of cameras. But methods specifically applied to direct stereo visual odometry are immature.
Our method is suitable for cameras with a gamma-like response function. In the beginning stage of processing, the disparity map is used to get corresponding points between the left image and right image in one frame pair. The parallel computing in GPU reduces the processing time of the disparity map generation step. The exposure time rate between frames is calculated from the brightness of feature point pairs between frames combined with vignetting reverse function. The method works when the left and right cameras are synchronous or have similar exposure times.
We apply the method to Stereo DSO (Stereo Direct Sparse Odometry) and SO-DSO (Direct Sparse Odometry with Scale Optimization). The experiments are applied on the open datasets and our stereo camera. The results of the experiment on the open dataset show that our method improves the accuracy of odometry. At the same time, the existing photometric calibration method shows its limitations in some sequences. We also apply the proposed method to our stereo camera data and show that the proposed method outperforms the conventional calibration method in the exposure time rate estimation. The odometry results are visually compared with the map reconstructed from the laser radar data, and the effectiveness of the proposed method is confirmed.

In Chapter 4, we discussed the point selection strategies in the direct methods. We propose a new technique using an edge detection method to extract pixels with distinct features in the image. The proposed edge detection method focuses on straight lines and long smooth curves. Based on the result of edge detection, we propose a keypoint selection method for DSO (Direct Sparse Odometry) and LDSO (Direct Sparse Odometry with Loop Closure). The description of the edge area avoids selecting the noise or a part of unstable objects such as moving leaves of trees as the key point.
We applied experiments on three open datasets. The experiment results show the proposed point selection method improves the accuracy of DSO and LDSO when the scene contains both man-made objects and natural objects. The increase in time cost is a disadvantage.
In Chapter 5, we made a summary and discussed future research.