（様式２）

学位論文の概要及び要旨

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題　　目　Calibrating Non-overlapping Cameras with a Laser Ray

（レーザを用いた視野の重ならないカメラの校正）

学位論文の概要及び要旨

ABSTRACT

This thesis focuses on the topics of calibrating non-overlapping cameras. Multi-camera system has been extensive applied in action recognition, Simultaneous Localization and Mapping, robot navigation, scene understanding and so on. It is necessary to calibrate relative pose between internal calibrated cameras. However, sometimes the cameras of the system may have non-overlapping view. Since the FOVs of the two cameras do not overlap, the conventional stereo camera calibration methods cannot be applied directly. This thesis deals with such a problem. The contributions of this thesis are two-fold: calibration of non-overlapping conventional RGB cameras and calibration of non-overlapping RGB-D cameras, e.g. Kinects.

For part 1 (calibration of non-overlapping conventional RGB cameras), this thesis aims at calibrating two in-vehicle cameras mounted back to back. Road sign detection is carried out by an outward-facing camera, and the monitoring of a driver's behavior is carried out by an inward-facing camera. To assess a driver's attention level, we need not only measure the gaze direction of the driver using the inward camera, but also map the estimated gaze direction to the coordinate system of the outward camera to determine what the driver is looking at. However, the mapping of gaze direction cannot be done without knowing the relative pose between the

inward and outward-facing cameras. Since the FOVs of the two cameras do not overlap, the conventional stereo camera calibration methods cannot be applied directly. Since one camera can measure the vehicle's motion while the other cannot, the consistency of motion cannot be used for camera calibration in this case. Since one of the cameras is situated inside the vehicle, it is difficult to set up a mirror with which the two cameras can observe the same scenes. This paper proposes a new approach to calibrate such non-overlapping cameras using a laser pointer, which can overcome the above problems. A laser pointer is mounted on a calibration board so that its pose within the coordinate system of the calibration board can be obtained. While one of the cameras, such as the inward camera, observes the calibration board with the laser pointer, the intersection of the laser ray and the outside scenery is observed by the other camera. Thus, the FOV of both cameras are connected and the relative pose between the cameras can be estimated. Two algorithms are presented based on this concept. In the first algorithm, the intersection of the laser ray and the object in the driver's FOV is observed by Camera 2. In this case, the relative pose between the cameras can be estimated through a coplanar constraint. In the second algorithm, Camera 2 observes another calibration board set up outside the vehicle, with which the laser ray intersects. Thus, a more rigid constraint, namely, the collinear constraint, can be used to estimate the relative pose between the cameras. We compare the performance of these two algorithms with the conventional mirror-based method presented in through simulations and experiments. We compare the performance of the two proposed algorithms with the conventional mirror-based method through simulations and experiments. Finally the laser-based collinear method is applied to the calibration of an in-vehicle camera system. In contrast to other methods, the proposed method is simple, practical, and especially well suited to the calibration of non-overlapping in-vehicle cameras in a factory or garage.

For part 2 (calibration of non-overlapping conventional RGB-D cameras), this thesis aims at calibrating two Kinects mounted on a mobile robot. The two Kinects monitor front and back respectively, so that the robot can go forward or backward anytime. To reconstruct the

environment in a unified coordinate system, the relative pose of two Kinects should be calibrated. However, in order to avoid interference between infrared rays of two Kinects, two Kinects should never have overlapping views. This thesis deals with above problem. Until now, several methods of calibrating non-overlapping RGB cameras have been reported. However, if the methods for RGB cameras are used directly to RGB-D cameras, the depth cues of RGB-D cameras is ignored without being exploited for the pose calibration of RGB-D cameras. In this thesis, we cope with the problem of calibrating non-overlapping RGB-D cameras, such as Kinects, by exploiting the depth cues. A laser pointer is fixed at one calibration board so that its pose at the coordinate system of the calibration board can be obtained easily. While one of the RGB-D cameras observes the calibration board fixed with the laser pointer, the laser pointer project a spot to the scene which is observed by the other. Thus, two 3D points, respectively located in the field of views of the two RGB-D cameras, are connected by a laser ray. The relative pose of two RGB-D cameras can be estimated through this collinear constraint. The effectiveness of the proposed method has been proved by results of simulation and real-world experiments.