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研　究　主　論　文　抄　録

論文題目　　Research on Moving Object Detection in Dynamic Outdoor Environments
（走行環境中移動体検知に関する研究）

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主論文要旨

《本文》In the work presented in this doctoral dissertation, I examine the issue of moving object detection, especially with regards to the problem of observer self-motion that arises with in dynamic outdoor environments.

First, a number of previously GMM estimation approaches, using monocular camera has intensively been proposed in the last decade. It forms the basis of vision-based motion analysis and obstacle detection, which detect moving objects by measuring the flow vectors difference between the objects (local motion) and background (global motion). However, calculating the accurate and dense optical flow vectors is a time consuming task. Binocular stereovision based GMM supplements depth (disparity) information to the model, thus global motion can be analyzed in 3D space rather than the traditional 2D image plane. Although good results have been obtained in many situations, it is still sensitive to image noise and large degree of rotation.

To overcome these problems, we selected gyroscope sensor for accurate rotation measurement. With the characteristics of self-contained, source-less and high sampling rate, gyroscope sensor is suitable for tracking the rapid motions like vehicle or aviation movement. However, since gyroscope sensor only measures the variation rate or

accelerations, the output signals have to be integrated to obtain the position and orientation data.

In the first part of this work, a new GMM estimation approach proposed through the fusion of 3D gyroscope and stereovision. We estimate the accurate distance change from camera to objects by an efficient feature-based tracking algorithm with stereovision. Combining the estimated global motion parameters, all features can be inverse-projected to the original image plane, and those objects that do not follow the global motion can be detected. To reduce the high calculation cost in stereo matching step, only corners are employed as features.

Furthermore, although camera provides large FOV and good resolution, and stereovision also can further provide depth information. However, vision depends very much on light conditions, when driving in urban areas these can change very much and consequently the degradation of image quality. Therefore the use of camera is not sufficient for reliable results.

To solve this problem, lidar based SLAM estimation has been seen as the prime tool to solve the so-called DAMTO (detection and tracking of moving objects) problem, since lidar provides precise and reliable position of objects. While SLAM provides the vehicle with a map of static parts of the environment as well as its location in the map, DATMO allows the vehicle being aware of dynamic entities around, tracking them and predicting their future behaviors. However, SLAM estimation in dynamic outdoor environments has been a difficult task since oblique road environments or different speeds, which may cause bias in raw data problem.

In order to solve this problem, we use a multi-layer laser scanner that also scans vertically, and which can therefore obtain the position of objects of different heights. By using the scanner, we have developed a method of road environment recognition based

vehicle's pitch angle compensation algorithm, the goal is improve on SLAM estimation for moving objects detection. After a consistent local map of the vehicle is constructed from SLAM, moving objects can be detected when new measurements arrive. The principal idea is based on the inconsistencies between observed free space and occupied space in the local grid map. If an object is detected on a location previously seen as free space, then it is a moving object. If an object is observed on a location previously occupied then it probably is static. If an object appears in a previously not observed location, then we can say nothing about that object. Real outdoor experimental result shows the effectiveness and efficiency of our approach.

Finally, an Occupancy Fusion Map (OFM) approach with sensor fusion is used for pedestrian detection was be describe. This work emphasizes the idea of redundancy or/and complementary due to the different data information provided by the laser scanner and stereovision. To realize a high performance of the system, ensuring the extension of single sensor efficiency would share with others sensors, it is necessary to integrate them, which complement each other and hence their combined information should enhance overall detection performance. Two approaches are presented to achieve the robust pedestrian detection result:

1) traditional OGM with stereovision for object detection suffers some major problems. Some objects cannot be detected because of discontinuous with the occupied data within the same object. To solve this problem, this work presents an innovation method of building OGM is proposed, which uses X-disparity grid instead of traditional X-Z grid. The advantage is obvious that our method can generate continuous occupied data, and therefore independent objects (blobs) could be more easily detected in OGM.

2) Another different tracking approach is also proposed in this work. Tracked information and sensors data are fused together, which is to solve the point-to-point

association with emphasis on object continuity assignment, and resolving the problem of two peoples are linked together and cannot be detected respectively.

The period over the past few years has seen significant growth in moving object detection in outdoor environments, especially with pedestrian detection and tracking. A number of experimental results show the effectiveness and efficiency of our approach.