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Time-Series Optimization Models Based on MVL-Fusion for Low-resolution 3D LiDAR

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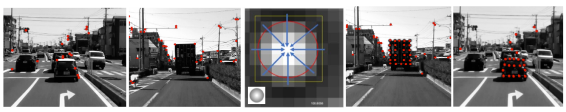
The laser scanner system of Light Detection And Ranging (LiDAR) has been the primary sensor for automated driving system due to its stability and reliable. Velodyne VLP-16, which in industrial-grade was be chosen of interest due to its low coat, Low-SWaP (size, weight and power) and High- High-RSaIP (range, safe and ingress protection-67). However, the number of laser beams limits its performance, defining it as low-resolution 3D LiDAR. To address the problem of degradation appears easily in dense and quality of point cloud and provide a low-cost solution, we propose a novel enhance method via fuse monocular vision and LiDAR (MVL).

In this paper, the PLK optical flow (KLT tracker) method is employed for motion estimation reference on LiDAR data as monocular visual front-end, and the pinhole camera perspective projection principle is used to build up the 3D-interpolation Feature Point model. The overview of Front-end vision/scanner model as shown in Fig.1 (c) . However, in practical scenarios, the feature extract performance is easily affected by various factors, which are the flow vectors of only a few of the most interesting pixels from the entire image. Then considering the feature of circular gradient characteristics, the virtual gradient (VG) method is proposed and imported. The detection rate was analyzed based on the number of added virtual gradient points, and the result of the optical flow to prove the effectiveness of our method. The result shows that the average detection was 91.77%, and the number of detected feature points increased by an average of 4 times, which make well performance than conventional KLT.

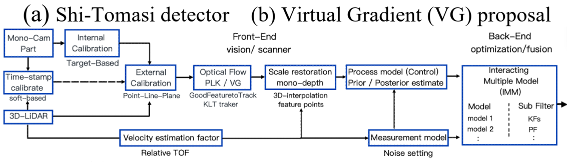
Also, for optical flow, there is instability (short time unavailable) and non-robustness, especially for facing with harsh environment or detecting far-distance objects. Morever, for maneuvering objects, the proposed interpolated model of 3D feature points cannot cope with the range, and the possibility of extremely low accuracy increases. Therefore, in order to extend the adaptive range of the proposed method, and balance prediction accuracy and computational cost, multiple time series filter prediction models are used in the IMM-based fusion to improve the overall data accuracy and robustness of the proposed method. The workflow and IMM structure as purposed model's back-end are shown in Fig.2 (a). By adjusting the 3 type of interact way (input/outpu IMMPF-ss/ps/pp, p-particle/s-state) alleviate the accuracy loss for generic PF in IMM model. The results shows that, IMMPF-pp has the highest accuracy with RMSE (0.175) in the performance of PF in the IMM model, but has the highest computation time compared to the 3 interact ways. Focusing on the balance between cost and accuracy, conversion to IMMPF-ps reduced computation time by 26% and improved accuracy by 28% than conventional IMMPF.

In addition, to bustup the computational efficient the fusion of Kalman filter series (KFs) and Particle filter is proposed in IMM. When the filter portion of the IMM model is replaced by a fusion type (IMMKPF-ps), the results are shown in Fig.2 (b). The accuracy has improved by 38% and time increased by 16% compared to IMMKF. Also compared to IMMPF-pp, the accuracy improved by an average of 23% and reduced time by an average of 17%. Moreover, the possibility of incorporating more model types and fusion methods into the model was also verified using real vehicle data, using Unscented PF (UPF) and Extended PF (EPF), an average accuracy improvement of 39.25% was observed compared to generic PF, and for typical vehicles and trucks It was verified that an average accuracy of RMSE (0.089) was obtained at a distance of 10 m. In addition, it was concluded that UPF and EPF were applied to reduce the computation time, and that more accurate prediction results could be obtained with guaranteed computation time.

For future works, more specific noise modeling for pedestrians, multiple objects should be considered to improve the applicability of the motion model to extend the filter. Also in harsh and high speeds scenario, the model accuracy in long distances should also be evaluated.

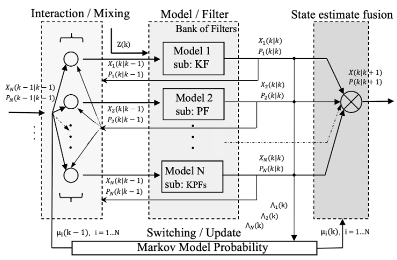


(a) Shi-Tomasi detector (b) Virtual Gradient (VG) proposal

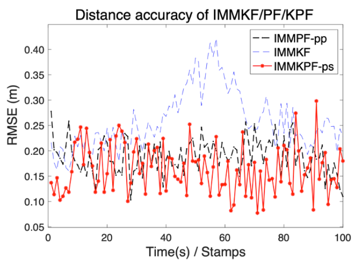


(c) The workflow of the proposed method

Fig.1 Overview of Front-end vision/scanner model



(a) Structure of purposed IMM



(b) Accuracy based on IMM-filters

Fig.2 Overview of Back-end optimization/fusion model