DVMM: A Dual-View Combination Descriptor for Multi-Modal LiDARs Online Place Recognition

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1 PARAMETER SETTINGS

Among the parameters involved in DVMM, only a couple of them, especially the elevation and azimuth angle intervals $\Delta\phi$ and $\Delta\theta$, the scaling factor α of Gaussian Kernel width, the cross-section descriptor size M^c and N^c, and the candidate number κ, need to be tuned. Their influence is evaluated on the Road03 sequence by measuring Recall@1 and runtime under different settings. Other parameters are summarized in Table 1.

The parameter $\Delta\phi$ controls the number of block rows ($2M^s$), which in turn affects the total number of rows in the radial descriptor ($2M^r$). We evaluate $\Delta\phi$ values of $[30°, 18°, 15°, 10°, 5°]$, corresponding to $2M^s = [6, 10, 12, 18, 36]$ and resulting in $2M^r = [16, 42, 60, 130, 524]$. A larger number of rows indicates greater retention of elevation information. As shown in Fig. 1(a), the runtime differences across $\Delta\phi$ settings are negligible. Therefore, $\Delta\phi = 15°$ is selected, as it yields the highest Recall@1. Additionally, an ablation study using equally elevation division into 60 rows (denoted as ER in Fig. 1(a)) consistently underperforms the adaptive grid projection, highlighting the superiority of the proposed projection method.

The parameter $\Delta\theta$ affects the number of columns N^r in the radial descriptor, with evaluated values of $[6°, 5°, 4°, 3°, 2°]$ corresponding to $N^r = [60, 75, 90, 120, 180]$. As shown in Fig. 1(b), increasing the number of columns improves the descriptor's discriminative capability in the yaw estimation, with only a marginal increase in runtime. Considering the trade-off between performance and efficiency, $\Delta\theta = 4°$ or $\Delta\theta = 3°$ is recommended.

The parameter α determines the Gaussian kernel width and is evaluated with values of $[0.1, 0.2, 0.3, 0.4, 0.5]$. A smaller α places greater emphasis on range features near the 0° elevation angle, which typically correspond to areas commonly observed by different LiDAR types. As illustrated in Fig. 1(c), the runtime remains almost unaffected by the choice of α. Therefore, we set $\alpha = 0.2$, which achieves the highest Recall@1 performance. Additionally, an ablation study is conducted using equal-weight averaging of range values within each column (denoted as EW in Fig. 1(c)). This strategy

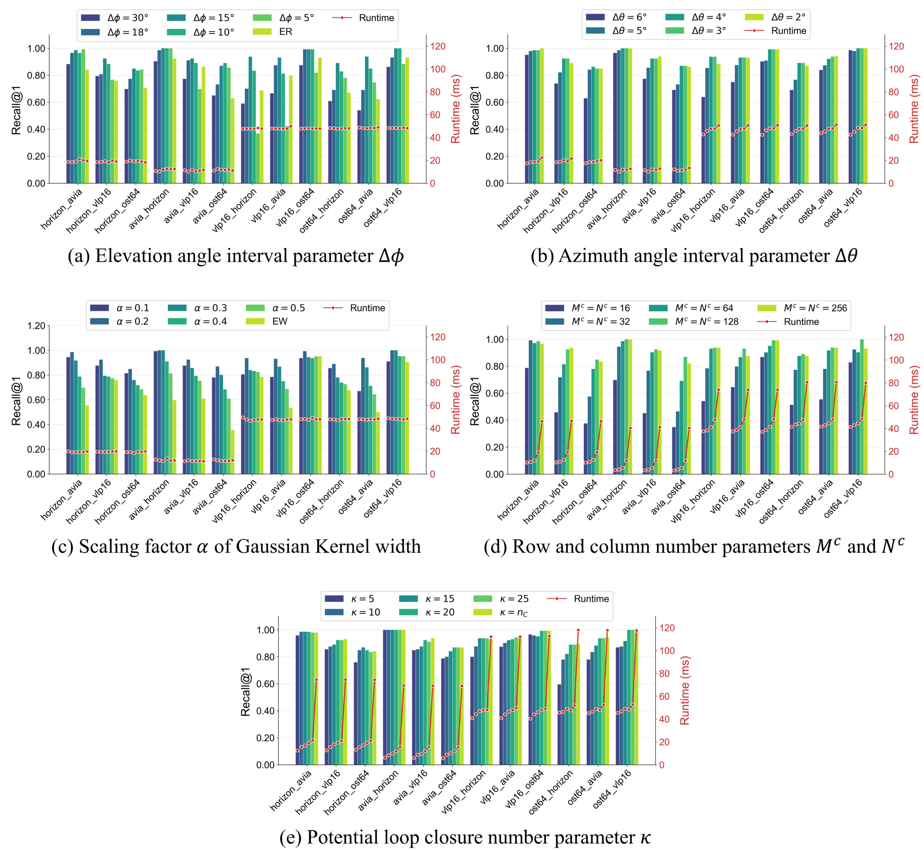
Table 1: Parameter Settings for DVMM

Parameter	Value	Description
n_f	10	Frames number to form a submap
$R_{\min}$,$R_{\max}$	2.0m, 50.0m	Submap range scope
ΔL	0.1m	Voxel size for downsampling
$\Delta\phi$,$\Delta\theta$	15°, 3°	Elevation and azimuth angle intervals for $\mathcal{R}$
α	0.2	Scaling factor of Gaussian Kernel width
$H_{\min}$,$H_{\max}$	2.0m, 5.0m	Height range scope for $\mathcal{C}$
M^c,N^c	128, 128	Row and column numbers for $\mathcal{C}$
κ	20	Potential loop closure number for validation

yields only acceptable results when applied to LiDARs with similar scan patterns, such as the Velodyne VLP-16 and Ouster OS1-64.

The parameters M^c and N^c define the size of the cross-section descriptor. Larger values enable finer structural representation and more accurate loop validation, but also result in significantly higher computational cost. Based on Fig. 1(d), we select $M^c = N^c = 128$ as a balanced configuration.

The parameter κ specifies the number of loop closure candidates passed to the validation stage. As shown in Fig. 1(e), Recall@1 saturates beyond $\kappa = 20$. Notably, when $\kappa = n_C$, all database candidates are included. Although this yields marginal improvements in Recall@1, it considerably compromises computational efficiency. Therefore, we select $\kappa = 20$ as the optimal configuration.



(a) Elevation angle interval parameter $\Delta\phi$

(b) Azimuth angle interval parameter $\Delta\theta$

(c) Scaling factor α of Gaussian Kernel width

(d) Row and column number parameters M^c and N^c

(e) Potential loop closure number parameter κ

Figure 1: Parameter Settings. The "horizon", "avia", "vlp16", and "ost64" correspond to the four types of LiDAR in the TIERS dataset: Livox Horizon, Livox Avia, Velodyne VLP-16, and Ouster OS1-64, respectively. In (a), "ER" denotes equal elevation angle resolution; in (c), "EW" denotes equal weighting; and in (e), n_C represents the total number of candidate point clouds in the database.