Supplementary Material for Multi-Echo Denoising in Adverse Weather

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1. Architecture

The architecture of the Coordinate and Correlation learner is a variant of 4DenoiseNet [2]. Fig. 1 describes the architecture in detail. The input is the feature tensor of the multi-echo neighbor encoder with self-excluded if the network corresponds to the Coordinate learner.

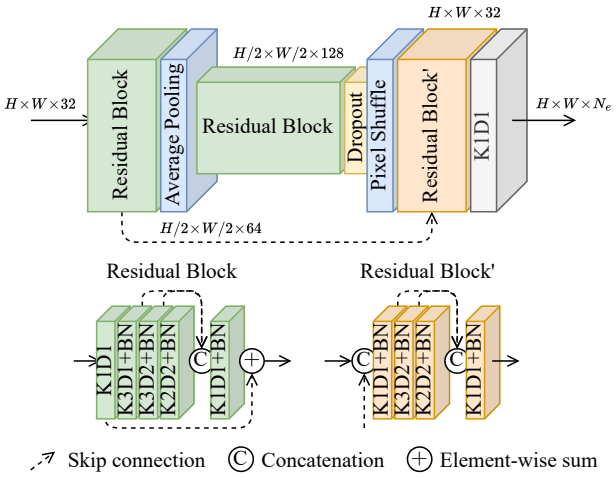

Figure 1. The architecture of the Coordinate and Correlation learner. K, D, and BN denote kernel size, dilation, and batch normalization, respectively.

2. Multi-Echo Dynamic Radius Outlier Removal

We modified the dynamic radius outlier removal (DROR) [1] to suit the purpose of multi-echo denoising. The modified algorithm is called multi-echo dynamic radius outlier removal (MEDROR). Algorithm 1 describes it in detail.

Algorithm 1 Multi-Echo Dynamic Radius Outlier Removal

Input: Multi-echo point cloud $\mathbf{P}_m$
Output: Inliers, Outliers, and Substitutes
$\alpha \leftarrow$ Angular resolution
$\beta \leftarrow$ A constant
$k_{min} \leftarrow$ Neighbor threshold
for $E_g \in \mathbf{P}_m$ **do** ▷ For all echo groups
  for $p \in E_g$ **do**
    $r_p \leftarrow ||p||_2$
    $SR \leftarrow \alpha \cdot \beta \cdot r_p$
    $k \leftarrow$ CountStrongestEchoNeighbors(p, SR)
    if $k < k_{min}$ **then**
      Outliers.append(p)
    else
      Inliers.append(p)
    end if
  end for
  if p_s is outlier and $\neg p_s$ is inlier **then**
    Substitutes.append$(\neg p_s)$ ▷ p_s is strongest echo and $\neg p_s$ is other than strongest echo
  end if
end for

References

[1] Nicholas Charron, Stephen Phillips, and Steven L Waslander. De-noising of lidar point clouds corrupted by snowfall. In *2018 15th Conference on Computer and Robot Vision (CRV)*, pages 254–261. IEEE, 2018. 1

[2] Alvari Seppanen, Risto Ojala, and Kari Tammi. 4denoisenet: Adverse weather denoising from adjacent point clouds. *IEEE Robotics and Automation Letters*, 2022. 1