AdaFit: Rethinking Learning-based Normal Estimation on Point Clouds

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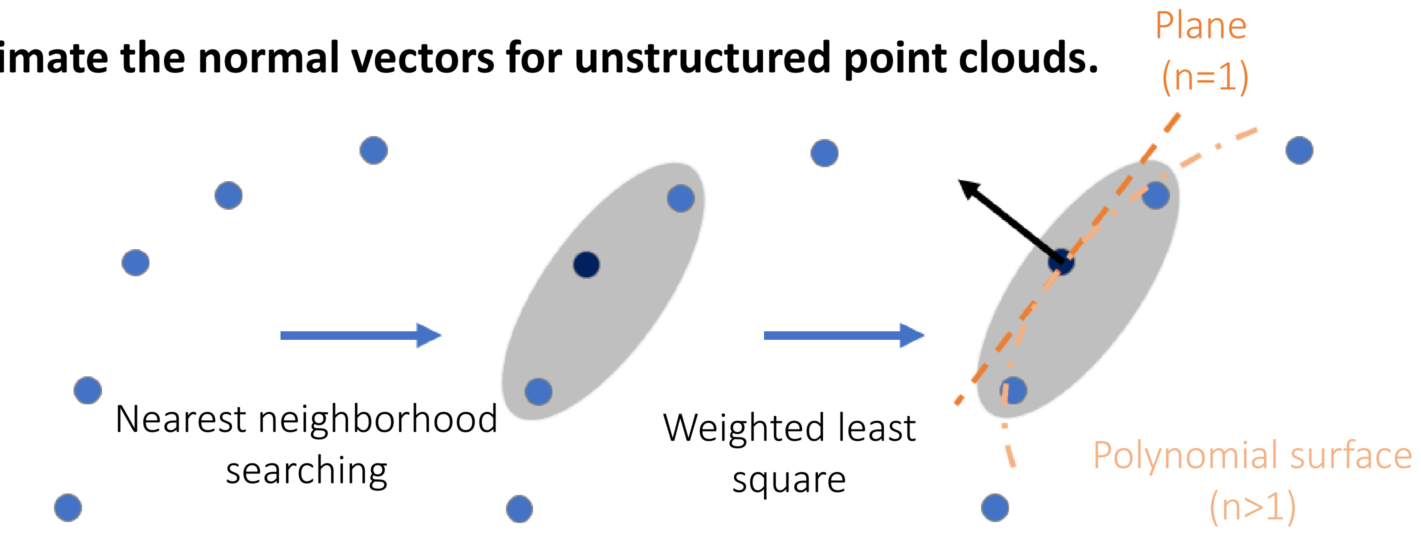
Project Page

Goal

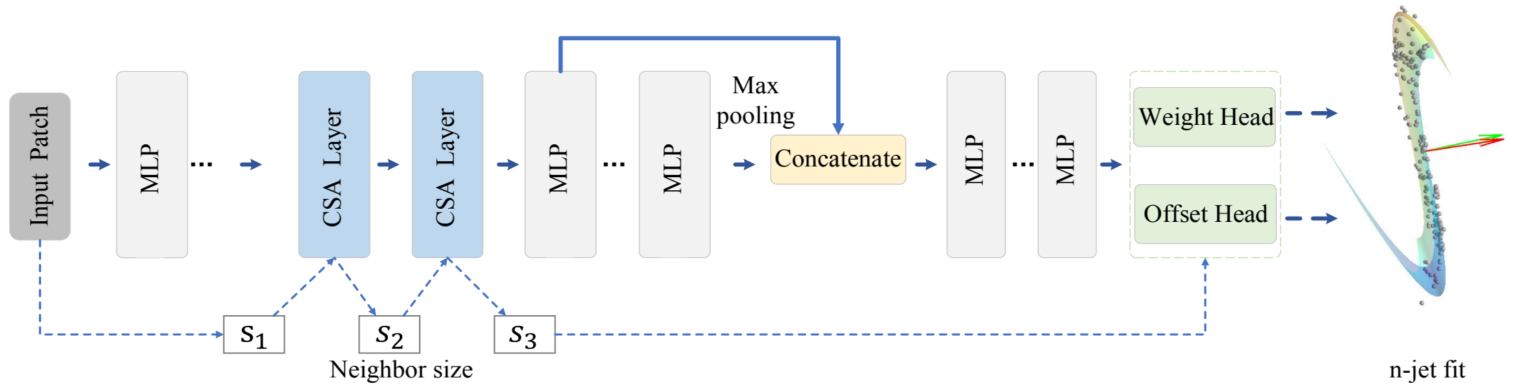
Estimate the normal vectors for unstructured point clouds.



Contribution

- We provide a comprehensive analysis on the weighted surface fitting and find two critical problems of these methods in normal estimation.
- We propose to predict offsets to adjust the distribution of neighboring points which brings more robustness and accuracy in normal estimation.
- We design the network AdaFit with novel CSA layers to enjoy benefits from both small and large scales, which achieves improved performance in multiple standard datasets.

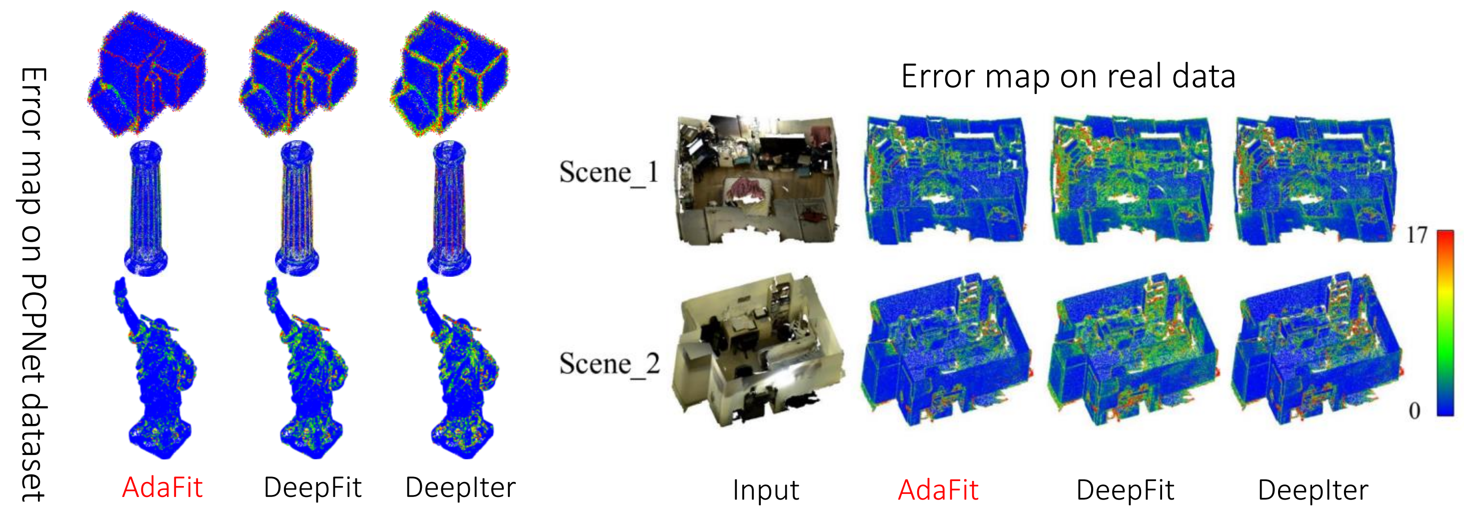
AdaFit Architecture



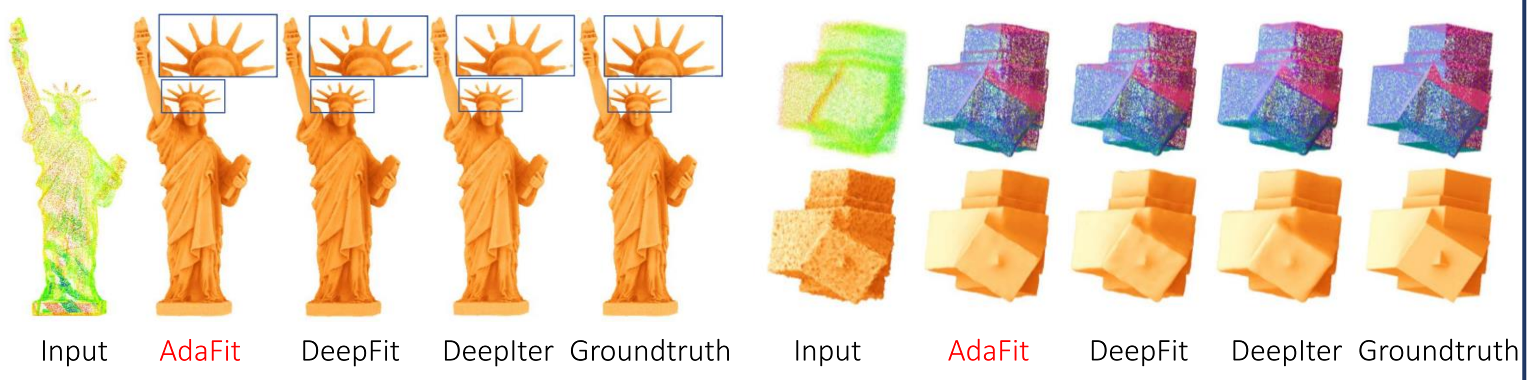
Results

Aug.	AdaFit	DeepFit [13]	Denoising+ DeepFit [13]	Lenssen *et al.* [15]	Nesti-Net [8]	PCPNet [7]	PCA [18]	Jet [22]
No noise	**5.19**	6.51	8.48	6.72	6.99	9.66	12.29	12.23
Noise ($\sigma = 0.00125$)	**9.05**	9.21	10.38	9.95	10.11	11.46	12.87	12.84
Noise ($\sigma = 0.006$)	**16.44**	16.72	16.79	17.18	17.63	18.26	18.38	18.33
Noise ($\sigma = 0.012$)	**21.94**	23.12	22.18	21.96	22.28	22.8	27.5	27.68
Varing Density(Strips)	**6.01**	7.92	9.62	7.73	8.47	11.74	13.66	13.39
Varing Density(gradients)	**5.90**	7.31	9.37	7.51	9.00	13.42	12.81	13.13
Average	**10.76**	11.8	12.8	11.84	12.41	14.56	16.25	16.29

Normal RMSE of AdaFit and baseline methods on the PCPNet dataset.



Application

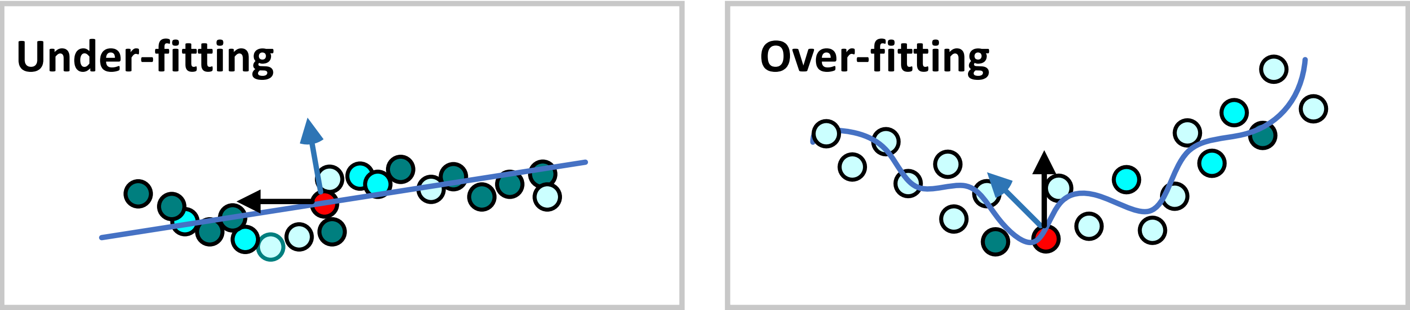


Surface reconstruction

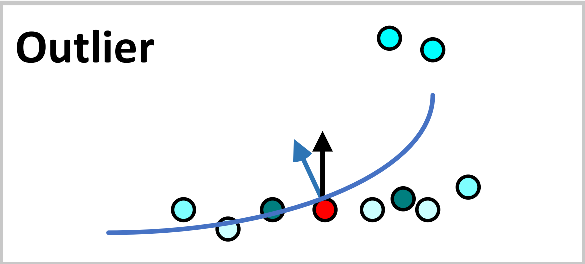
Denoising

Challenges

- How to accurately fit a surface with the presence of noise and outliers?
  - Inconsistent Polynomial order n (Hard to choose an optimal n)



  - Sensitive to outlier



Proposition 1. *For a specific point p_i, if it is farther from the fitted surface in Eq. 1, which means the predicted height $z'_i = J_n(\beta, x_i, y_i)$ on this point is largely deviated from the input height z_i, then the weight on this point will have a larger impact on the fitted surface, i.e.* $\partial\beta/\partial w_i = (M^\intercal W M)^{-1} M_i^\intercal (z_i - z'_i)$.

- How to select an optimal neighborhood size?
  - Large scale: robust to noise ☺; oversmoothing ☹
  - Small scale: accurate ☺; sensitive to noise ☹

Method

I. Offset-learning

- Propose to learn the point-wise offset to adjust the distributio of the patch
- Use the points after offsetting for weighted least square surface fitting (avoid the problem of inconsistent polynomial orders and is robust the outliers)

$$\beta = \underset{\alpha}{\operatorname{argmin}} \sum_{i}^{N_p} w_i \| J_n(x_i + \Delta x_i, y_i + \Delta y_i; \alpha) - (z_i + \Delta z_i) \|^2$$

II. CSA layer